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### CONTENTS OF THE NUMBER FOR MAY 1940.

| CONTENTS.   | Page. |
|---|-------|
| I. Side wear on rails and point tongues, by A. JACOBS . . . . .   | 147   |
| II. Electrification of the Paris-Irun (Spain) line. Completion of the final section, from Tours to Bordeaux, by Jacques DUMAS . . . . .   | 153   |
| III. Surface hardening of steel cylindrical parts by means of high-frequency currents, by Dr.-Ing. H. HAILUK . . . . .  | 169   |
| IV. American refrigerator wagons, by Helmut BAUR. ( <i>To be continued</i> ) . . .  | 173   |
| V. Fifty years of the Bulgarian State Railways (1888-1938). ( <i>Concluded</i> ) . .  | 183   |
| VI. NEW BOOKS AND PUBLICATIONS:   |       |
| Cours d'exploitation des Chemins de fer. Tome II: <i>Exploitation technique. Signalisation</i> (2 <sup>e</sup> partie) ( <i>Railway Operating Course. Vol. II. Technical Operation. Signalling, Part 2</i> ), by Ulysse LAMALLE . . . . . | 198   |
| VII. MONTHLY BIBLIOGRAPHY . . . . .   | 35    |

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# BULLETIN

OF THE

# INTERNATIONAL RAILWAY CONGRESS

## ASSOCIATION

(ENGLISH EDITION)

[ 623. 145.5 & 623. 151 ]

## Side wear on rails and point tongues

by A. JACOPS,

Engineer, Belgian National Railways Company.

To lay down limits to the side wear allowable on rails and point tongues is one of the most difficult problems in railway engineering, especially at a time when the economic factor demands first consideration in all branches of railway working.

If formerly it was permissible to take a rail out of service long before the wear on it had reached the safety limit, it is of the utmost importance at the present time to pay much stricter attention to the phenomena met with at the point of contact between wheel and rail and to retain permanent way material in service as long as it is safe to do so.

At one time, too, points — which are the parts of the permanent way most subject to side wear — were run over on the diverging line almost uniformly at a speed of about 40 km. (25 miles) an hour; nowadays those having a diverging line taken at 120 km. (75 miles) an hour are by no means rare. It is true that the maximum speeds allowed, determined as a function of the curvature, always give rise to substantially the same effort on the outer rail, but the consequences of an accident — for it is against derailments that it is essential to guard — are

decidedly more serious when traffic passes at high speed than when it is moving at a relatively low one.

It is really quite surprising to see, after a little thought on the subject, on what small factors the safety of running rests; it is not even a matter of a wheel flange [the depth of which may vary according to the R. I. C. — the agreed international standards on the subject — from 25 to 36 mm. (1 in. to 1 7/16 in.)], but a very small point of contact, which differs but little from the mathematical point.

Regulations issued by the rolling stock department lay down normal forms and limits of wear allowable for wheel tyres.

We will not dwell further on this here beyond recalling that paragraph 21/10 of the R. I. C. says that « the wheel flange must not be allowed to wear so much that it becomes a sharp edge ».

As regards the maximum side wear permitted for rails and points, the diversity of the regulations in force on the different railway systems shows how complex the problem is and that its ideal solution has not yet been arrived at.

Following certain accidents in Belgium — fortunately few in number — the

National Railways Company also instituted very thorough investigations, which led to the new regulations at present in force on its system, as reported below.

On a first enquiry into the matter it becomes clear that the tendency of a wheel to mount the rail depends entirely on the frictional resistance at the point where the wheel flange touches the worn

in determining what degree of safety obtains;

3. The offset  $f$  of the hollow in the worn face, which is generally concave; the practice of setting a limit to this, tried for a time on the Belgian railway system, gave no practical results and was particularly difficult to apply to point tongues.

4. The degree of inclination  $\alpha$  of the chord of the worn face with respect to the vertical (to simplify the discussion we will assume the track to have neither super-elevation nor gradient); this factor is of no use to us as such, for it is beyond dispute that, given the concavity of the worn face, the conditions of equilibrium sought for are not identical, but depend upon whether contact takes place in the upper or lower worn portion of the rail head.

It is, however, of importance to analyse the behaviour of the forces acting on the rail at each point of the worn face and to consider, with respect to each one, only the factor really differentiating it from the others, namely the inclination of the plane tangent at that point.

It would be useless to try and establish the precise point of contact on the wheel; indeed the special shape of the wheel flange and that which, in the course of time, the rail head assumes, taking the curvature of both into account, are so complex that such an investigation would be extremely laborious; it would also be necessary to add to it the effects due to variations in the curvature of the rail and the position, more or less oblique, taken up by the axle, all very uncertain factors in the case.

A much simpler line of reasoning, however, is able to bring us to a solution of the problem: seeing that a wheel, by supposition, bears against a rail by its flange,

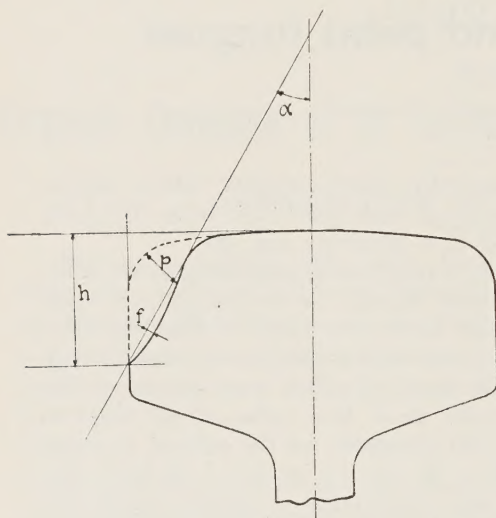


Fig. 1.

face of the rail head, and that the danger is to be found in practice far more in the shape of this face than in the reduced amount of metal in the rail head.

The characteristic elements constituting a worn face in a cross section of rail are (Fig. 1):

1. The height  $h$ ; in our view there is no interest in setting a limit to this, because the worn face is hollowed out by the passage of the wheels themselves and cannot therefore assume a form at variance with that of the wheel flanges;

2. The depth  $p$ ; in our opinion this does not, merely of itself, play any part

especially during a possible climbing movement, there is always some point of contact on the side face of the rail. The common plane tangent at this point possesses a degree of inclination defined by the tangent at the same point, on the contour of the transverse section of the rail. We have from now on only to consider the cross sectional shape of the rail, whether the plane of the axis of the axle passes through it or not.

Let us suppose that a new wheel is running in a normal manner, but with the

results from this; it even appears little probable that the axle could ever rise sufficiently to make the angle of contact become less than  $32\frac{1}{2}^\circ$ .

Bold as the statement may appear at first sight, our colleague Mr. G. MOULART, who was associated with us in these investigations, pointed out that if a new tyre has a face inclined at  $30^\circ$  the rail may be allowed to wear until its worn face reaches an equal degree of inclination. Nevertheless one is led to ask oneself whether this figure may be exceeded and, if so, to what extent; this remains to be proved by calculation.

Let us suppose that we have a rail, the concave worn surface of which has clearly exceeded, at its lower portion, the

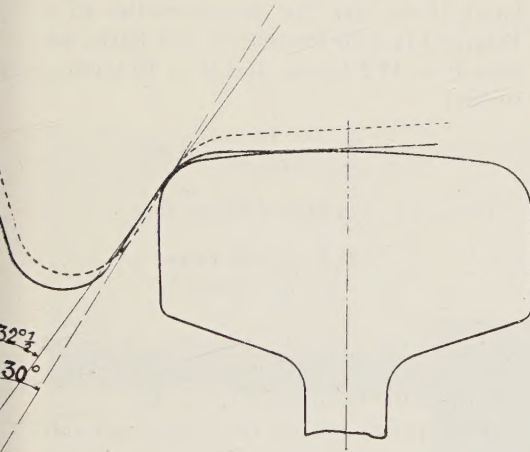


Fig. 2.

flange making contact, on a new rail (Fig. 2); the sections we have chosen for illustration are those in use in Belgium. The sketch shows that the contact between flange and rail is made at an inclination of  $32\frac{1}{2}^\circ$ . Should the interaction of the various forces cause the flange to ride up against the rail the contact would then take place following the conicity of the flange, which in transverse section appears as an inclined straight line set at approximately  $30^\circ$  to the vertical.

Experience proves that no disadvantage

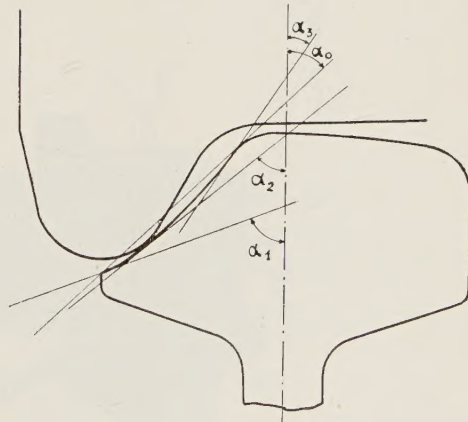


Fig. 3.

permissible limits of inclination, and a wheel which has started to climb (fig 3). Starting with an angle of inclination  $\alpha_1$  the wheel would successively encounter tangent planes less and less inclined to the vertical ( $\alpha_2, \alpha_3$ ); the degree of inclination  $\alpha_0$  of the chord of the worn face is but a very rough average of these figures. It is logical to admit that if a certain limit of inclination were to be

reached and passed, the wheel would cease to bear against the rail and would tend to fall back on the track. From this we conclude that if the tangent plane at the upper edge of the worn face presents an inclination  $\alpha_s$  inferior to the limit stated above, the danger of climbing exists no longer, whether rails or point tongues are in question.

The degree of safety obtaining may be determined by calculating the value of the co-efficient of stability against slipping, that is to say the relation  $n$  between the force  $T$ , which tends to produce slipping along the worn face inclined at an angle  $\alpha$ , of any value, and the frictional resistance  $F$ , acting in opposition (Fig. 4).

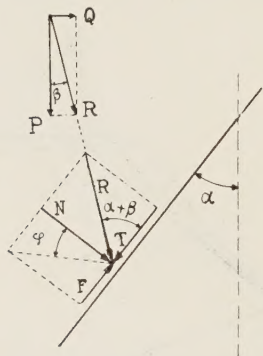


Fig. 4.

$R$  is the resultant of the weight  $P$  of a loaded wheel and the transverse effort  $Q$  acting on the rail.

The inclination of  $R$  with respect to the vertical is expressed by  $\tan \beta = \frac{Q}{P}$  and its inclination with respect to the worn face is given by the angle  $(\alpha + \beta)$ . Its component perpendicular to the face  $N = R \sin (\alpha + \beta)$ , and its tangential component is  $T = R \cos (\alpha + \beta)$ .

Finally the frictional force is  $F = N \tan \varphi$ , where  $\varphi$  represents the angle of friction.

$$\begin{aligned} \text{Then } n &= \frac{T}{F} = \frac{R \cos (\alpha + \beta)}{N \cdot \tan \varphi} = \\ &= \frac{R \cos (\alpha + \beta)}{R \sin (\alpha + \beta) \tan \varphi} = \\ &= \frac{\cot \varphi}{\tan (\alpha + \beta)} = \frac{\cot \varphi (1 - \tan \alpha \tan \beta)}{\tan \alpha + \tan \beta}. \end{aligned}$$

Now it may be admitted that  $\tan \varphi = 0.25$  and  $\cot \varphi = 4$ . On the other hand, if we take the characteristics of a Belgian Class 10 locomotive as a basis, we have  $P = 11.2$  tonnes and  $Q = 10$  tonnes, so that

$$\tan \beta = \frac{Q}{P} = \frac{10}{11.2} = 0.893.$$

From all of which follows that

$$n = \frac{4(1 - 0.893 \tan \alpha)}{\tan \alpha + 0.893}$$

and the equilibrium between opposing forces ( $n = 1$ ) will be obtained when the value of the angle  $\alpha$  is  $34^\circ 10'$ .

The application of the theory set out above is possible only in so far as we have at our disposal some practical means of fixing with exactness the inclination of the tangent plane at any point on the surface of the rail section.

Means of doing this were found by making a material representation of the plane tangent to a cylindrical surface (the curvature of the rail is left out of account, being negligible with the length concerned when measuring) : the limit constituted by a secant plane passing through two adjacent generating lines brought almost into contact. A straight-edge was made, having faces accurately parallel, one of them bearing two ribs of equal height spaced 10 mm. (25/64 in.)

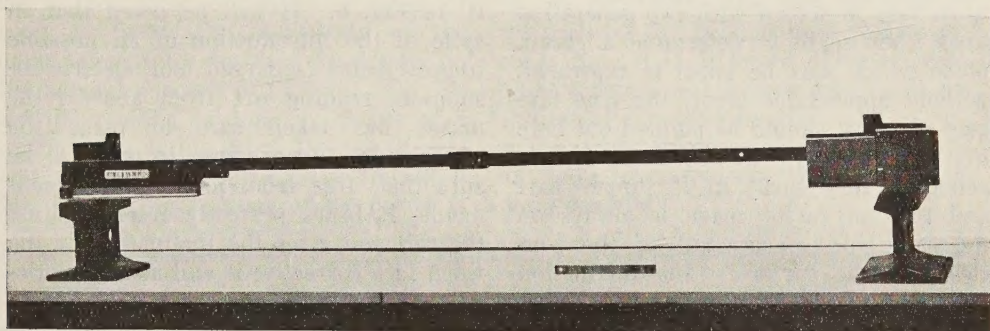


Fig. 5.

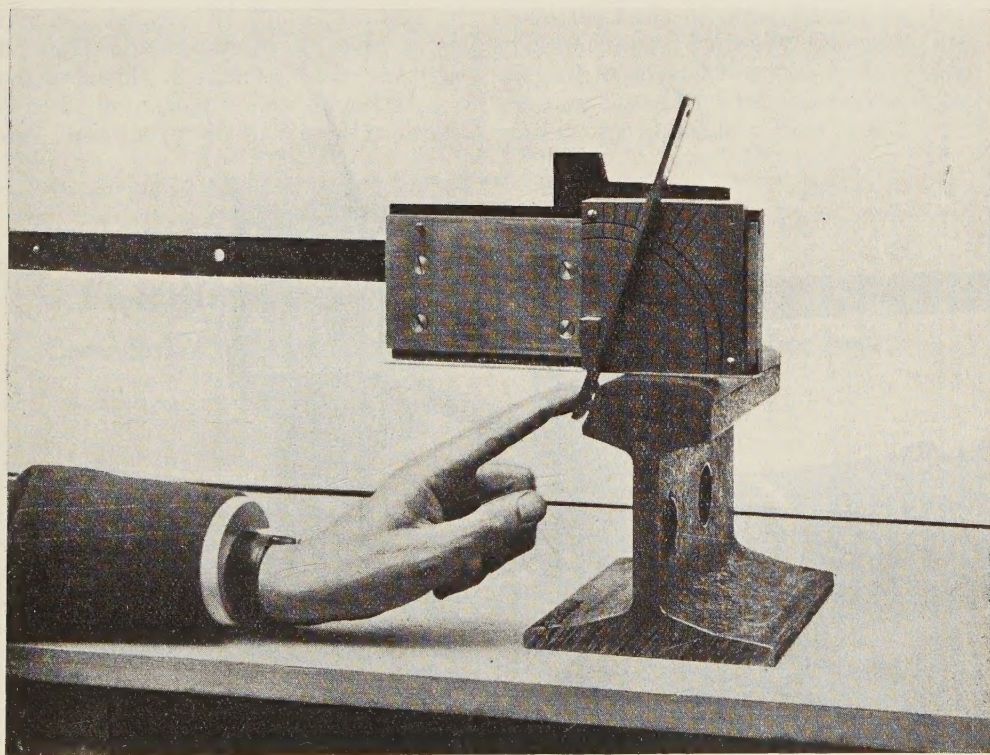


Fig. 6.

apart; if these ribs are applied to the worn face in accord with two generating lines, they serve to determine a secant plane which may be taken to represent, without appreciable error, the true tangent plane; it should be pointed out here that the curvature of the worn face is generally very small in its upper part and that any error made is always on the safe side, on account of the concavity of the surface. The inclination being thus fixed, it is sufficient to place behind the straightedge a graduated circle, the zero mark being placed perpendicular to the plane of the track, to enable the degree of wear to be read off.

The complete measuring apparatus is

shown in Fig. 5; the method of using it, in Fig. 6. It will be noted that in spite of the introduction of all possible improvements (enlarged foot, electric insulation, reading off from above), the maker has taken care to make the straightedge independent, in order to be sure that, free from mechanical attachments, it bears perfectly freely against the rail and gives the inclination of the worn face correctly; it will also be noticed that the graduated circle is made to slide, to enable the operator to bring the centre of the circle, represented by the edge of a cube, carefully into contact with the straightedge.

There is also a simpler form of this

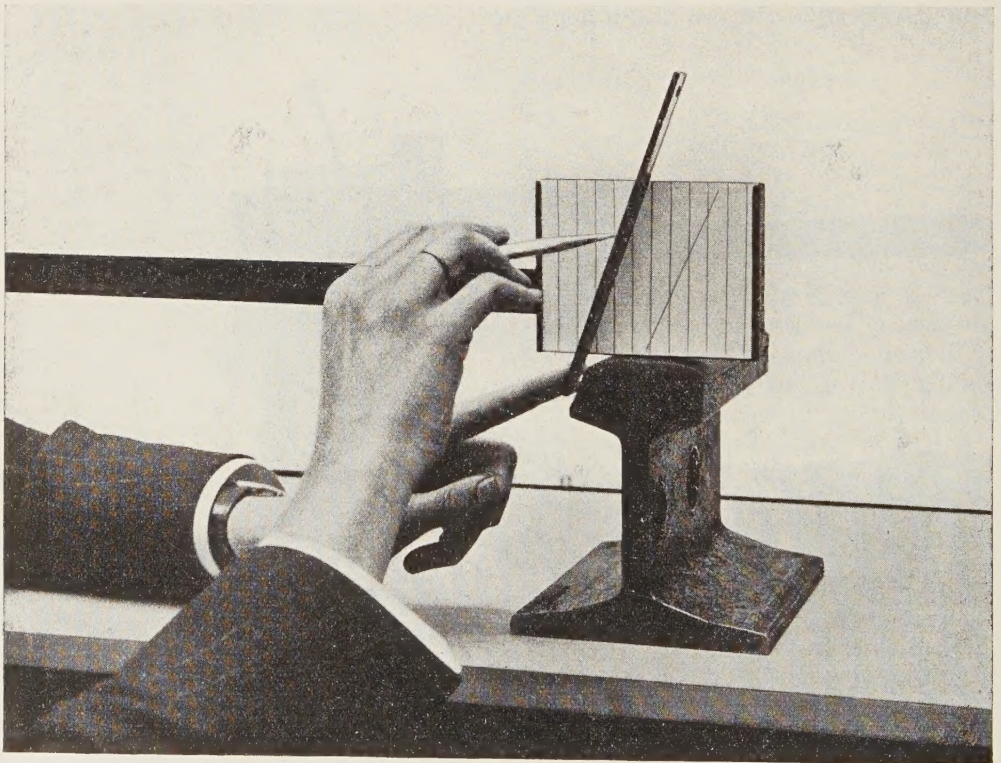


Fig. 7.

device; instead of a graduated circle it has a face plate on which a sheet of paper is fixed; the inclination of the plane tangent to the face is drawn on this paper by means of a pencil (Fig. 7), and the reading is done by means of a protractor, starting from the set of vertical lines previously marked on the sheet. This less expensive form of the device is

It is found, when making observations on the permanent way, that the wear of the rails on the Belgian lines seldom exceeds 25°. It is different, however, with point tongues, which have been made the subject of extended enquiry.

The table below combines the results of 8 500 measurements taken on single point tongues.

| Degree of wear.            | Less than 30° | 30°    | 31°    | 32°    | 33°    | 34°    | 35°    | More than 35° |
|----------------------------|---------------|--------|--------|--------|--------|--------|--------|---------------|
| Percentage.                | 95.64 %       | 1.64 % | 1.02 % | 0.53 % | 0.47 % | 0.27 % | 0.15 % | 0.28 %        |
| Co-efficient of stability. | —             | 1.32   | 1.24   | 1.17   | 1.09   | 1.02   | 0.94   | —             |

intended for use by those members of the staff who have only to make a few measurements at a time, while the type with the graduated circle is for taking a large number of direct, rapid readings.

On the basis of these figures the Belgian National Railways Company has decided to adopt 32° as the limit of side wear on the main lines and engine lines, and 34° for subsidiary lines.

[ 621. 53 (.44) ]

## Electrification of the Paris-Irun (Spain) line.

### Completion of the final section, from Tours to Bordeaux,

by JACQUES DUMAS, Ingénieur E. S. E.

(*Le Génie Civil.*)

The commencement of electrical operation on the Angoulême-Bordeaux line on the 19th December 1938, marked the completion of the last section, from Tours to Bordeaux, of the main-line from Paris to the Spanish frontier (Irun); the first two portions of this section (Tours-Poitiers and Poitiers-Angoulême) were put into commission in 1938, on the 17th June and 5th July respectively. The electrification of the other sections of the line was completed

as follows: Paris-Orléans, 1926; Orléans-Tours, 1933; Bordeaux-Dax, 1927; Dax-Hendaye, 1926; and Hendaye-Irun, 1929 (1).

It is thus possible for trains to be hauled by electric locomotives (fig. 1)

(1) The electrification of these various sections has been described in the *Génie Civil* as follows: Paris-Orléans, in the issue of December 25, 1926; Orléans-Tours, on July 29, 1933, and Bordeaux-Hendaye on July 30, 1927.

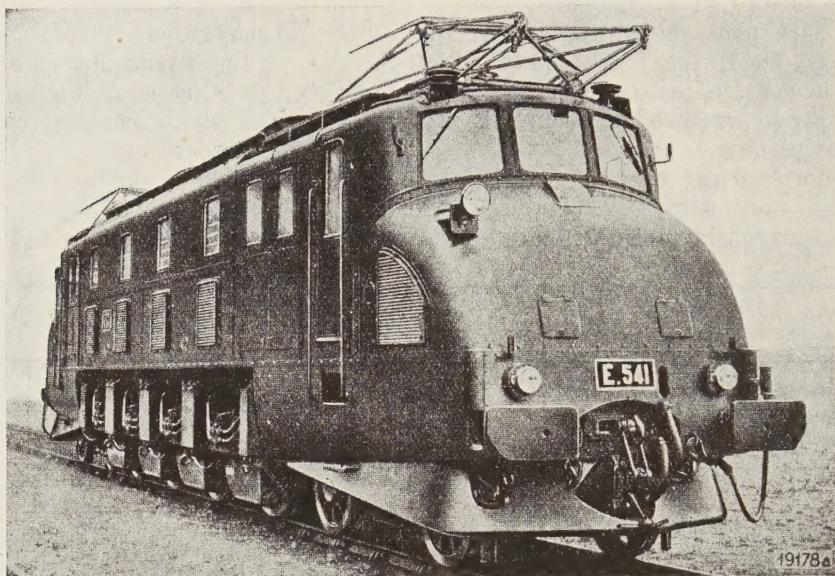


Fig. 1. — Paris-Irun electrification. 4 000-H.P. 2 D 2 locomotive for express services, built by Messrs. Cie. Electro-Mécanique.

for the whole distance from Paris to Irun (824 km. = 512 miles), which is the longest electrified line in Europe, and one of the longest in the world.

In this article we propose to give an outline of the development of electrification in France, with especial reference to the Orléans and Midi Systems, which to-day form the South-Western Region of the French National Railways Company; then to describe the power supply arrangements provided for this Region and, finally, to mention the main features of the Paris-Irun electrification, especially as regards the Tours-Bordeaux section, which has benefited from the experience gained in the operation of the previous sections.

#### **Historical survey of electrification on the French railways.**

The development of electric traction on railways in France has taken place in two stages separated by the 1914-1918

war, each characterized by entirely different tendencies :

1. Before the 1914-1918 war, the initiative for electrification was left to the Railway Companies, who in this way electrified a total of 243 km. (151 miles) of line on various systems of traction, of which 22 km. (13.7 miles) was on the Orléans Railway, and 169 km. (105 miles) on the Midi.

2. This state of affairs was changed completely by the 1914-1918 war. Actually, France only produces 50 million tonnes of coal per year, whereas the yearly consumption is 70 million tonnes. It is therefore necessary to import 20 million tonnes, a considerable portion of which is consumed by the Railways, who have special need of it, since it is advisable to burn the majority of French coals mixed with a certain proportion of foreign coal.

The very high price of coal during the 1914-1918 war and, above all, the appreciable difficulties experienced in

satisfying the demands of consumers on account of the occupation of the greater part of the French mining districts, compelled the Government, in 1917, to turn its attention to making general use of the considerable sources of hydraulic power available in France, especially for traction purposes. In 1919, the Railway Companies, at its invitation, presented a general electrification programme covering nearly 9 000 km. (5 600 miles) of line, of which 2 540 km. (1 580 miles) were on the Orléans System, and 3 150 km. (1 960 miles) on the Midi.

the electrification schemes drawn up by the Railway Companies. As a result, an additional 3 112 km. (1 934 miles) of line was electrified, 978 km. (608 miles) of which on the Orléans System, and 1 696 km. (1 054 miles) on the Midi. These extensions have increased the annual consumption of electrical power on the French main-line railways to 650 million kilowatt-hours, which has meant a saving of more than one- and-a-half million tonnes of coal per year. Electrical operation accounts for 35 % of the total traffic on the former Orléans System, 70 % on the former Midi System,

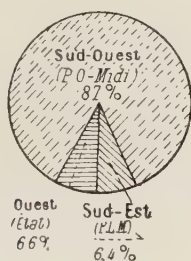


Fig. 2

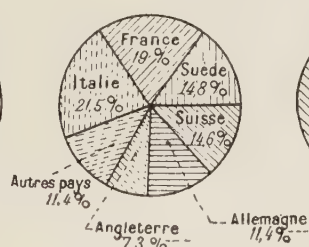


Fig. 3

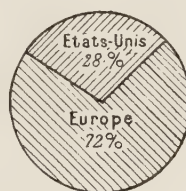


Fig. 4

Figs. 2 to 4. — Proportion of lines electrified in France, in Europe and in the world.

Explanations of French terms in :

Fig. 2. — Sud-Ouest, etc. = South-Western Region (former Paris-Orléans and Midi Railway Companies). — Ouest (Etat) = Western Region (former State Railways). — Sud-Est = South-Eastern Region (former P. L. M. Rys.).

Fig. 3. — Suède = Sweden. — Suisse = Switzerland. — Allemagne = Germany. — Angleterre = England. — Autres pays = other countries.

Fig. 4. — Etats-Unis = U. S. A.

At this point it became obviously necessary to standardise the system of electrification to be adopted. For this purpose the Government set up a special technical committee which, after making a close study of the various systems in use both in Europe and America, declared in favour of direct current at 1 500 volts. This choice was confirmed by a Ministerial Decree dated August 29th, 1920 <sup>(2)</sup>, which at the same time adopted without much alteration

and 50 % of the whole traffic on the two systems together.

At the present time the total length of electrified lines in France amounts to 3 355 km. (2 085 miles) of which there are 1 000 km. (621 miles) on the former Orléans System and 1 865 km. (1 159 miles) on the former Midi Railway, or 14 % and 43 % respectively of the total length of line on the two Railways. The South-Western Region of the French National Railways Company which has replaced the former Orléans and Midi Railways since January 1st, 1938, has therefore a total of 2 865 km. (1 780 miles) of line electrified, or 25 %

<sup>(2)</sup> The reasons which led to the choice of 1 500-volt direct current have been set out in the issue of the *Génie Civil* for 23rd April 1921.

of its whole length, and 87 % of the total length of electrified track in France (fig. 2).

In short, France owns 19 % of the total length of electrified lines in Europe, amounting to 18 500 km. (11 496 miles) (fig. 3); it therefore takes second place among the countries of Europe, close to Italy, which occupies the first place with 21.5 %. Finally we may observe that Europe possesses 72 % of the world's electrified lines (fig. 4). against 28 % in the United States.

*Development of electric traction on the Orléans and Midi Railway Systems.*

The two stages mentioned above may be noticed in this development also.

1. Before the 1914-1918 war, the Orléans and Midi Companies only used electric traction to meet local operating conditions, for heavy traffic, or for working hilly sections of line.

To take an example, in 1900 the Orléans Company adopted the 600-volt D. C. system with third rail for operating their trains on the new line just constructed in Paris, almost wholly underground, to transfer the Austerlitz terminus to the more centrally situated Orsay Station <sup>(3)</sup>. In 1904 the Company extended this system of traction to the suburban lines between Austerlitz Station and Juvisy (18 km. = 11.2 miles), where traffic is particularly heavy. However, investigations carried out in 1910 showed that the electrification of lines with current generated in steam power stations did not produce sufficient operating economies to warrant the considerable capital expenditure required for the scheme.

As regards the Midi, this Company had intended since 1902 to use electric traction on the metre-gauge mountain line which was to be constructed

between Villefranche-de-Conflent and Bourg-Madame (56 km. = 34.8 miles) in French Cerdagne <sup>(4)</sup>. As a matter of fact, this method of operation was the only one possible on this line, on account of the long 1 in 17 gradients which it contains. The construction of this line was considerably delayed for various administrative reasons, but it was finally put into commission in 1910-11 with the third rail system at 850 volts D. C., and is still working at the present time unaltered. The adoption of electric operation was also decided in the same way for the two lines across the Pyrenees, from Oloron to Canfranc by the Somport, and from Ax-les-Thermes to Puigcerda by the Puymorens, the concession for which was taken up in 1907 by the Midi Company; these lines have gradients as steep as 1 in 23.

Moreover, in their desire to take advantage of the particularly abundant sources of water-power in the Pyrenees, which border all the southern portion of their System, the Midi Company embarked on a large-scale electrification scheme in 1908, covering 950 km. (590 miles) of line; this scheme was authorised by the Act of 17th July, 1908, and the Decree of 8th June, 1910. However, before proceeding with this scheme the Company thought it would be as well to try out the single-phase system of electrification at 12 000 volts, 16 2/3 cycles, with overhead contact line, which had given such excellent results abroad, in particular in Switzerland, and it was decided to electrify the standard-gauge line from Perpignan to Villefranche <sup>(5)</sup> (46 km. = 28.6 miles) on this system. This line was opened in 1913 and is still operating with excel-

<sup>(4)</sup> The line from Villefranche-sur-Têt to Bourg-Madame was described in the *Génie Civil* for 4th and 11th May, 1912.

<sup>(5)</sup> The line from Perpignan to Villefranche was described in the *Génie Civil* for 28th December, 1912, and 18th January, 1913.

<sup>(3)</sup> The extension of the line between Austerlitz and Orsay stations was described in the issue of the *Génie Civil* for 25th January, 1902.

lent results on the same system, with the original rolling-stock. These encouraging results induced the Midi Company to adopt this system for the electrification of various branches of their Pau-Montréjeau line in the direction of the Pyrenees, and when the war broke out (1914), electric working was in operation on three of these branches, totalling 67 km. (41.6 miles) in all.

2. After the 1914-1918 war, in order to conform with the Government circular of 29th August, 1920, which made the use of 1 500-volt D. C. compulsory and approved the electrification programmes drawn up by the Companies in 1919 at the invitation of the Government, the Orléans and Midi Railways, whose electrification projects extended over 2 540 km. (1 578 miles) of lines and 3 150 km. (1 957 miles) of track, had to convert their existing equipment in addition to proceeding with the electrification of additional lines (fig. 6).

Thus it came about that after considering the electrification of their mountain lines in the « Massif Central », the Orléans Company from 1924 to 1926 electrified the heavily loaded section from Juvisy to Vierzon, with the branch from Brétigny to Dourdan, and in addition converted the former third-rail 600-volt D. C. equipment on the Paris-Juvisy line. Electric operation was afterwards introduced on the Orléans-Tours section in 1933, and from Vierzon to Brive in 1935.

For their part the Midi Company first converted the few branches running towards the Pyrenees from the Pau-Montréjeau line, which had been equipped before the 1914-1918 war on the single-phase 12 000-volt system, and then proceeded from 1922 to 1931 to electrify the line from Toulouse to Dax and Bayonne as well as all the Pyrenees branches, and also the Bordeaux-Irun line with the Lamothe-Arcachon branch. These were followed by the Béziers-Neussargues section in 1932, the Bor-

deaux-La Pointe de Grave line in 1934, and that from Montauban to Sète in 1935.

Finally, in 1938, the South-Western Region of the French National Railways Company extended electric working to the Tours-Bordeaux line, thus connecting the already-electrified Paris-Tours and Bordeaux-Irun sections, and enabling trains to be worked electrically from Paris right to the Spanish frontier.

#### **Power supply for the South Western Region of the French National Railways Company.**

The arrangements for the supply of power for traction purposes have been developed in a manner similar to the electrification schemes, and here again two stages are noticeable :

1. Originally, the use of electric traction was confined to particular cases which concerned quite short portions of line, and so the Railway Companies were satisfied to provide independent power supplies for their various electrified lines.

For instance, the Orléans Company constructed the Quai de la Gare power station, in Paris, to supply their Paris suburban lines electrified on the 600-volt D. C. system. This is now been converted into a sub-station.

For its part, the Midi Company built on the Têt two hydro-electric power stations, La Cassagne (3 200 kW.) and Fontpédrouse (2 200 kW.), for feeding the 850-volt D. C. line from Villefranche-de-Conflent to Bourg-Madame and the 12 000-volt single-phase 16 2/3-cycle line from Perpignan to Villefranche respectively; these power stations still supply these two lines under the same conditions.

2. After the 1914-1918 war, the extensive railway electrification recommended by the Upper Council for Public Works was to be the first step towards the general electrification of the country, rendered possible by the progress made in methods of high-tension

power transmission over long distances. In particular, the generating stations required had to be so laid out and designed that the maximum possible use was made of the available sources of hydraulic power, and the energy generated had to be distributed not only to the railways, but also to consumers with needs of a different kind, such as industrial and power supply companies. The arrangements for feeding the railways had therefore to be considered under two heads: firstly, generation in power stations which as far as possible should be hydro-electric; and secondly, transmission over long distances by means of a system of high-tension lines.

There is considerable difference in the methods adopted by the Orléans and Midi Companies in this connection, and we shall consider them separately.

#### *Power supply for the Orléans System.*

To meet its own power supply requirements the Orléans Company has turned to the sources of water power in the « Massif Central ». First of all, in conjunction with the « Union d'Electricité », an associated company, the « Union hydroélectrique », was formed to build the Eguzon power station (50 000 kW.) on the Creuse (6); then the Company itself constructed the Coindre station (24 000 kW.) on the Rhue, a tributary of the Dordogne, and the Marèges station (128 000 kW.) on the Dordogne (7). The main features of these power stations are given in Table I.

Finally, in order to make up for irregularities in the flow of the rivers in the Massif Central, where the lowest water level occurs in Summer, these generating stations were inter-connected with the steam power stations in the Paris district, where there is appreciable

(6) The Eguzon power station was described in the *Génie Civil* for 3rd July, 1926.

(7) The Marèges power station was described in the *Génie Civil* for 7th July, 1934 and 26 October, 1935.

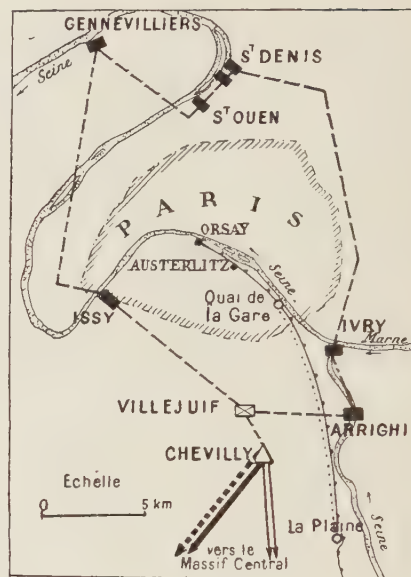


Fig. 5. — Details of electrification in the Paris district.

Note. — Echelle = scale. — Vers le Massif Central = to the « Massif Central ».

current available in Summer on account of the reduction of load on the power distribution systems fed from them.

This was achieved by the construction of a 220-kV. transmission line (8), 422 km. (262 miles) long, (figs. 5 and 6), between the transforming stations of La Môle, near the Marèges power station, and Chevilly, near Paris, via the transforming stations at Eguzon, near the Eguzon power station, and Chaingy, near Orléans. The main features of these transforming stations are given in Table II. This main transmission line was then duplicated by a second 220-kV. line constructed by the « Société pour le Transport de l'Energie du Massif Central » between the La Môle and Chaingy stations, and by the « Union

(8) The 220 000-volt transmission system between the « Massif Central » and Paris was described in the *Génie Civil* for 10th December, 1932.

| Power station.    | Net normal head. | Source of supply (River or lake).                      | Effective volume of water in reservoir. | Pipe lines. |  | Generating sets.     |         |                  |                    | Output of power of station.  | Output capacity in an average year. |
|-------------------|------------------|--|---|-------------|--|----------------------|---------|------------------|--------------------|------------------------------|-------------------------------------|
|                   |                  |  |   | Number.     | Internal diameter.                     | Length.              | Number. | Type of turbine. | Alternator output. | Alternator terminal voltage. |                                     |
|                   | m. (feet).       |  | m <sup>3</sup> (Br. gall., millions).   |             | m. (ft. in.).                          | m. (feet).           |         |                  | kW.                | kV.                          | kWh. × 10 <sup>6</sup>              |
| Ciindre . . .     | 115 (377)        | Rhues.   | 2 800 000 (616)                         | 3           | 1.55 (5' 1")                           | 181 (594)            | 3       | Francis.         | 8 000              | 5.5                          | 95                                  |
| Marèges . . .     | 72 (236)         | Dordogne.  | 35 000 000 (7 700)                      | 4           | 4.00 (13' 1 1/2")                      | 127 to 146 (417 479) | 4       | Francis.         | 32 000             | 12                           | 325                                 |
| Eguizon (*) . .   | 58 (190)         | Creuse.  | 54 000 000 (11 879)                     | 2           | 4.25 (13' 11 5/16")                    | 100 (328)            | 5       | Francis.         | 10 000             | 10.5                         | 120                                 |
| Soulom . . .      | 240 (787)        | River Cauterets.                                       |   | 3           | 0.81 (2' 7 7/8")                       | 530 (1 739)          | 3       | Pelton.          | 2 400              |                              | 80                                  |
|                   | 113 (371)        | River Pau.   |   | 3           | 1.20 (3' 11 1/4")                      | 330 (1 083)          | 3       | Francis.         | 2 400              | 10.5                         |                                     |
| Eget . . .        | 710 (2 329)      | Lake of Orédon, Cap de Long, Aubert, Anmar and l'Oule. | 26 000 000 (5 720)                      | 7           | 0.56 (1' 10")                          | 1 250 (4 101)        | 7       | Pelton.          | 3 500              | 6                            | 110                                 |
| Artouste . . .    | 773 (2 536)      | Lake Artouste and rivers Bious.                        |   | 3           | 0.60 to 0.80 (1' 11 5/8" — 2' 7 1/2")  | 1 555 (5 102)        | 3       | Pelton.          | 7 000              | 10                           | 21 000                              |
| Miegébat . . .    | 380 (1 247)      | Brousset and Soussouçon.                               | 23 000 000 (5 060)                      | 3           | 1.20 & 1.23 (3' 11 1/4" & 4' 0 7/16")  | 750 (2 461)          | 5       | Pelton.          | 7 000              | 10                           | 35 000                              |
| Houat . . .       | 204 (669)        |  |   | 2           | 1.62 & 1.68 (5' 3 13/16" & 5' 6 3/16") | 330 (1 083)          | 5       | Francis.         | 7 000              | 10                           | 35 000                              |
| Lassoula (**)     | 430 (1 411)      | Lake Caillaonas and Neste de Pouchergues.              | 18 000 000 (3 960)                      | 1           | 0.90 to 1.10 (2' 11 1/2" — 3' 7 5/16") | 2 200 (7 218)        | 3       | Pelton.          | 3 700              | 10                           | 11 100                              |
| Tramezaygues (**) | 433 (1 421)      |  |   | 1           | 1.00 to 1.30 (3' 3 3/8" — 4' 3 7/32")  | 880 (2 887)          | 3       | Pelton.          | 4 500              |                              | 65                                  |
|                   | 245 (804)        | Neste de Lapez.  |   | 1           | 0.65 (2' 1 5/8")                       | 685 (2 247)          | 2       | Pelton.          | 1 250              | 10                           | 16 000                              |

(\*) This power station is owned by the « Union Hydroélectrique », a subsidiary of the French National Rys. Co.  
(\*\*) These stations are owned by the « Société Hydroélectrique du Midi », a subsidiary of the French National Rys. Co.

d'Electricité » between Chaingy and Chevilly.

These two principal 220-kV. lines have a total capacity of 100 000 kW. They receive energy from a number of generating stations and supply various 90-kV. lines which distribute supplies to substations on the different electrified routes. The system is completed by two 90-kV. lines between Chevilly and La Martinerie substation, near Limoges, thence by a single line to La Môle; these lines also feed the traction substations on the Paris-Brive railway line.

Chevilly is connected to the 60-kV. underground network supplied by the various steam generating stations in the Paris district <sup>(9)</sup>: Gennevilliers (220 000 kW.) and Arrighi (200 000 kW.), belonging to the « Union d'Electricité »; Saint-Denis I (60 000 kW.), Saint-Denis II (150 000 kW.) and Ivry (60 000 kW.), worked by the « Société d'Electricité de Paris et de la Seine »; Saint-Ouen (250 000 kW.) and Issy (130 000 kW.), belonging to the « Compagnie parisienne de Distribution d'Electricité ». The Eguzon transforming station is connected by 10 500-volt lines to the Eguzon power station (50 000 kW.) of the « Union hydroélectrique »; La Môle is connected by 90-kV. lines to: Coindre (24 000 kW.) owned by the Orléans Company; Roche-le-Peyroux (30 000 kW.) owned by the « Société des Forces Motrices de la Diège »; Lamativie (29 000 kW.) and Laval-de-Cère (25 000 kW.) owned by the « Société hydroélectrique de la Cère »; and to the Orléans Company's station at Marèges (128 000 kW.), to which it is also connected by two 220-kV. lines. Finally, the main double 220-kV. line has been extended by the addition of two 220-kV. lines constructed by the « Société de Transport de l'Energie du Massif Central » between La Môle and Ruyres transforming stations. At the latter terminate the 220-kV. lines

from the Sarrans (102 000 kW.) and Brommat (175 000 kW.) power stations belonging to the « Société des Forces Motrices de la Truyère » <sup>(10)</sup>.

This inter-connection between the hydro-electric stations of the « Massif Central » and the steam stations in the Paris district provides the Orléans Company with two sources of supply possessing all the safeguards to be desired; in addition, the power stations in the « Massif Central » are furnished with storage reservoirs of considerable size, and are able to provide supplies not only for traction purposes, but also for consumption peaks in the Paris district. For this reason some of the power stations in the « Massif Central » have been considerably over-equipped: for instance, Marèges, the last station built by the Orléans Company, has been equipped for an output of nearly four times the average output available.

To ensure the satisfactory operation of this group of inter-connected power stations <sup>(11)</sup>, a central control has been set up in Paris, at the offices of the « Union d'Electricité », 3, rue de Messine; this organisation controls the working of the hydro-electric stations, apportioning the load between the latter and the steam stations and maintains constant frequency. The reactive power necessary for voltage and power factor regulation is provided at La Môle transforming station by the alternators of Marèges; at Eguzon by those of Eguzon generating station; and at Chaingy and Chevilly by synchronous compensators, details of which are given in Table II.

#### *Power supply for the Midi System.*

The Midi Company has drawn on the sources of water power in the Pyrenees

<sup>(10)</sup> The Brommat and Sarrans power-stations were described in the *Génie Civil* for 17th September, 1932 and 24th June, 1933.

<sup>(11)</sup> Cf. *Génie Civil*, 8th January, 1938, for an article on the working of this interconnection.

<sup>(9)</sup> Detailed descriptions of these have appeared in the *Génie Civil*.

TABLE II. — Particulars of transforming stations of the South-Western Region of the French National Railways Company.

| Station.                     | Groups of 3 single-phase transformers. |         |                     |                 | Synchronous compensators. |         |                       |                 |
|------------------------------|--|---------|---------------------|-----------------|---------------------------|---------|-----------------------|-----------------|
|                              | Voltage.                               | Number. | Capacity per group. | Total capacity. | Voltage.                  | Number. | Capacity per machine. | Total capacity. |
|                              | kV.                                    |         | kVA.                | kVA.            | kV.                       |         | Reactive kVA.         | Reactive kVA.   |
| La Môle . . . . .            | 220-90                                 | 2       | 60 000              | 120 000         |                           |         |                       |                 |
| Eguzon . . . . .             | 220-90-10.5                            | 1       | 30 000              | 30 000          |                           |         |                       |                 |
|                              | 90-10.5                                | 3       | 24 000              | 72 000          |                           |         |                       |                 |
| Chaingy . . . . .            | 220-90-6.6                             | 1       | 40 000              | 40 000          | 6.6                       | 1       | 20 000                | 40 000          |
|                              | 90-6.6                                 | 1       | 20 000              | 20 000          |                           |         | 10 000                |                 |
| Chevilly . . . . .           | 220-60-11                              | 3       | 75 000              | 225 000         | 11                        | 3       | 45 000                | 135 000         |
|                              | 90-60                                  | 2       | 25 000              | 50 000          |                           |         |                       |                 |
| Pessac . . . . .             | 150-60-6.6                             | 2       | 20 000              | 40 000          | 6.6                       | 2       | 15 000                | 30 000          |
|                              | 150-90                                 | 1       | 25 000              | 25 000          |                           |         |                       |                 |
| Dax . . . . .                | 150-60-6.6                             | 1       | 20 000              | 20 000          | 6.6                       | 2       | 8 000                 | 16 000          |
| Laruns . . . . .             | 150-60                                 | 2       | 20 000              | 40 000          |                           |         |                       |                 |
| Lannemezan . . . . .         | 150-60-11                              | 1       | 30 000              | 30 000          |                           |         |                       |                 |
|                              | 150-60                                 | 1       | 20 000              | 20 000          |                           |         |                       |                 |
| Portet-Saint-Simon . . . . . | 150-60-11                              | 1       | 30 000              | 30 000          | 11                        | 1       | 30 000                | 30 000 (*)      |
|                              | 150-60-6.6                             | 1       | 20 000              | 20 000          | 6.6                       | 2       | 8 000                 | 16 000          |
| Saint-Victor . . . . .       | 150-60                                 | 1       | 25 000              | 25 000          |                           |         |                       |                 |

(\*) This compensator is unusual in that it operates in hydrogen and is of the outdoor type. See article in *Génie Civil* for 7th April 1934, p. 325.

for its electrical energy <sup>(12)</sup>: the first generating stations to be constructed were Soulom (14 400 kW.) on the Pau and the Cauterets mountain torrents, and Eget (24 500 kW.) on the Neste de Conplan; next came Hourat (35 000 kW.), Miegibat (35 000 kW.), and Artouste (21 000 kW.), arranged in cascade formation in the Ossau valley; moreover, a subsidiary company, the « Société hydroélectrique du Midi », was formed by the Midi to build the Lassoula (11 100 kW.) and Tramezaygues (16 000 kW.) power stations on the Neste de Caillaouas and the Neste de Lapez <sup>(13)</sup>. The

<sup>(12)</sup> The Midi Company's generating stations were described in *Génie Civil* for 21st and 28th September 1918, 25th August 1923, 6th August 1927, and 4th August 1928.

<sup>(13)</sup> Tramezaygues and Lassoula power stations were described in the *Génie Civil* for 4th March 1933.

main features of these are given in Table I.

In addition, the Midi Company constructed a 150-kV. power transmission system, comprising (fig. 6) firstly, two lines between the transforming stations of Laruns, near Hourat power station, and Pessac, near Bordeaux, via Jurançon sectioning point, near Pau, and Dax transforming station; and secondly, a single line between Jurançon and Saint-Victor transforming station, near Millau, via the transforming stations of Lannemezan and Portet-Saint-Simon, near Toulouse, between which two latter points it is duplicated by a second 150-kV. line. Each of these lines has a capacity of 50 000 kW.; they take supplies from a large number of generating stations and feed the substations through 60-kV. distribution lines. The main details of the

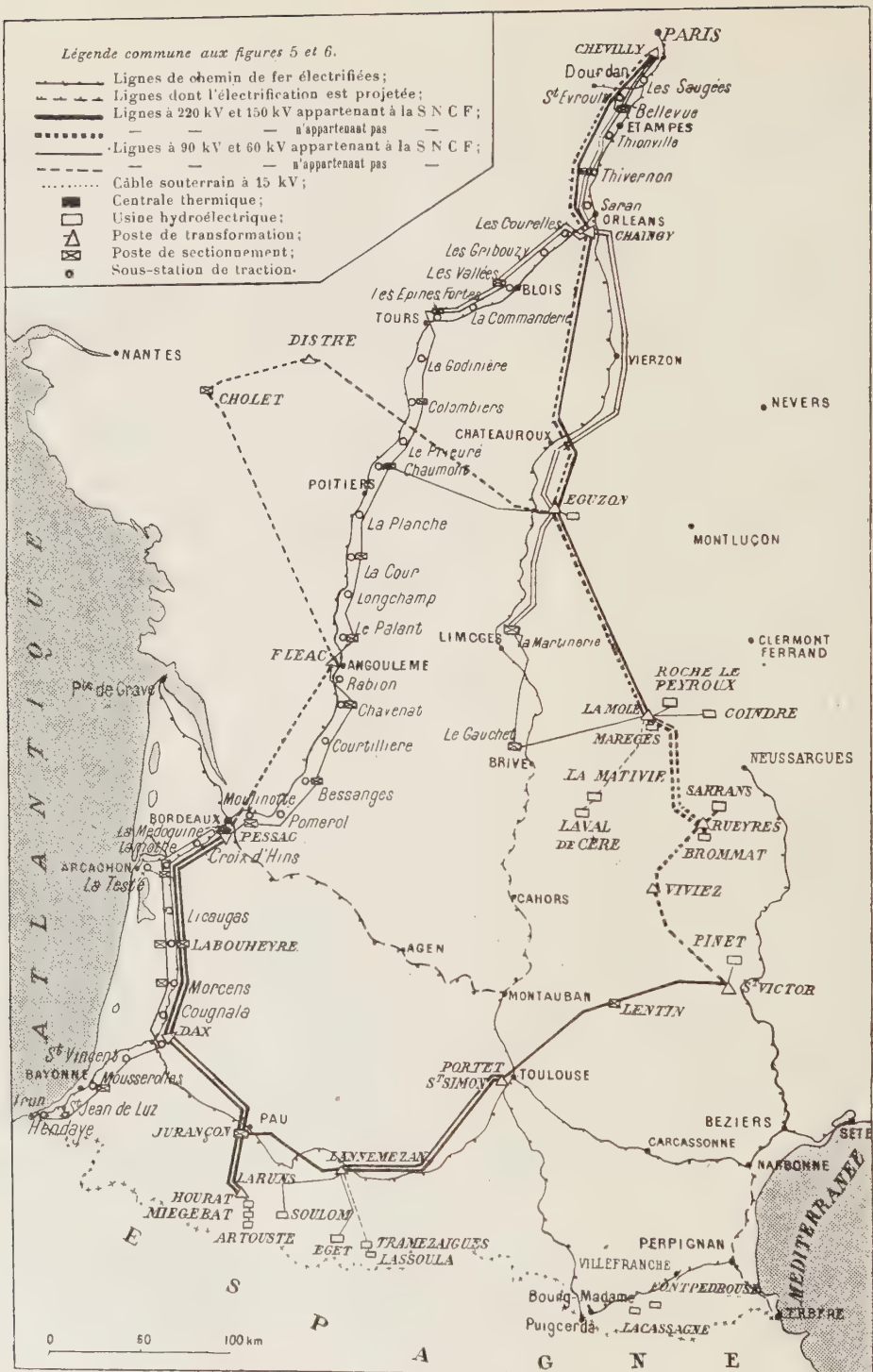


Fig. 6. — General map showing electrification of the South-Western Region of the French National Railways Company, based on a more detailed map prepared by the « Cie Electro-Mécanique », under the direction of Mr. Garnier.

*Explanation of French terms in Fig. 6 :*

Légende commune aux figures 5 et 6 = references common to figs. 5 and 6. — Lignes de chemin de fer électrifiées = electrified railway lines. — Lignes dont l'électrification est projetée = lines proposed for electrification. — Lignes à 220 kV. et 150 kV. appartenant à la S. N. C. F. = 220-kV. and 150-kV. lines belonging to the French National Railways Company. — Do... n'appartenant pas... do... do... not belonging to... do. — Câble souterrain à 15-kV. = 15-kV. underground cable. — Centrale thermique = steam powerstation. — Usine hydroélectrique = hydro-electric power station. — Poste de transformation = transforming station. — Poste de sectionnement = Switching station. — Sous-station de traction = traction substation.

transforming stations are given in Table II.

Laruns transforming station is connected through 60-kV. lines to the three cascade power stations, Hourat, Miégebat and Artouste (total output 91 000 kW.). Similarly, Lannemezan transforming station is linked up through 60-kV. lines to Soulom, Eget, Tramezaygues and Lassoula power stations (total output 66 000 kW.), and Saint-Victor is connected by a 60-kV. line to Pinet generating station (32 000 kW.), on the Tarn, owned by the « Rouergue » Company. The Midi high-tension network is also connected to a large number of power stations owned by private companies.

To ensure the satisfactory operation of all these inter-connected power stations, a special authority has been created, the « Union des Producteurs d'Energie des Pyrénées occidentales », which combines the chief electric power companies using the Midi Company's transmission lines. This authority determines the load distribution between supply companies and regulates supplies to the consumers, and in addition maintains correct frequency. The control point is located at Lannemezan. The reactive power required for voltage and power-factor regulation is supplied at Lannemezan by the alternators at Eget, at Laruns by those at Hourat, at Saint-Victor by the machines at Pinet; and at Pessac, Dax and Portet-Saint-Simon, by synchronous compensators, details of which are given in Table II.

### *Inter-connection of the Orléans and Midi Companies' power transmission systems.*

Interconnection between the Orléans

Company's 220-kV. lines and the Midi's 150-kV. system is provided (fig. 6) : (a) between Eguzon and Pessac, by the 220-kV. line from Eguzon to Distré, and by the 150-kV. line from Distré to Cholet, Fléac and Pessac, owned by the « Société Anonyme de Transport d'Energie du Centre et de l'Ouest »; (b) between La Môle and Saint-Victor, by the duplicate 220-kV. lines belonging to the « Société de Transport d'Energie du Massif Central », from La Môle to La Rueyres, and by the 150-kV. line from Rueyres to Viviez and Saint-Victor, owned by the « Société de Transport Rouergue-Auvergne ».

In addition, the 90-kV. lines feeding the substations on the Orléans-Bordeaux section link up Chaingy and Eguzon with Pessac; and finally, the proposed 90-kV. line between Brive and Montauban will provide a connection between La Môle and Portet-Saint-Simon, as well as supplying the substations on the Brive-Montauban section when this is electrified.

### **Principal features of the Paris-Irun electrification.**

We shall now give a few particulars concerning the Paris-Irun electrification <sup>(14)</sup>, with special reference to the feeding arrangements, substations, contact system and rolling stock.

#### *Feeder system.*

Except for the two Paris substations, one in Paris itself, and the other in the

(14) General information on the Orléans and Midi electrification schemes were given by Mr. Bachellery in *Génie Civil* for 27th November, 1937.

inner suburbs, which are fed through 15-kV. underground cables, the substations on the Paris-Irun line are supplied by means of overhead transmission lines. Those between the Paris suburbs and Tours are fed through two 90-kV. lines on account of the heavy traffic on this section, which also affords better safeguards against breakdown. Substations between Tours and Bordeaux receive their supply at 90-kV., and those between Bordeaux and Irun are fed at 60-kV. These lines are connected to the H. T. network at Chevilly, near Paris; Chaingy, near Orléans; Fléac, near Angoulême; Pessac, near Bordeaux; and Dax. In addition, there is a 90-kV. line which provides a direct connection between Chaumont substation, near Poitiers, and Eguzon transforming station (fig. 6).

For the 90-kV. lines steel-cored aluminium cables are employed, of 238 mm<sup>2</sup> (0.369 sq. in.) section, composed of 37 strands, 7 of which are of steel. These cables are secured to independent towers, with an average spacing of 250 m. (273 yards), by means of cap-and-pin type insulator chains, composed of 6 elements in the suspension type, and 2 × 7 elements in parallel at anchoring points. These insulator chains are protected at each end by arcing horns. The minimum height of the cables above ground level at the centre of the span is 9 m. (29 1/2 ft.). A galvanised steel cable, of 60-mm<sup>2</sup> (0.093 sq. in.) cross-section attached to the tops of the towers forms the earthing cable.

Just before reaching the terminal station at Pessac, the 90-kV. line from Tours to Bordeaux incorporates two spans more than 500 m. (546 yards) in length, for the Dordogne and Garonne crossings. For these it has been necessary to provide towers more than 70 m. (230 ft.) high.

The 60-kV. line between Bordeaux and Hendaye is carried on the « Gothic arch » type structures supporting the

contact system (fig. 9). Aluminium cables of 172 mm<sup>2</sup> (0.267 sq. in.) cross section are used between Pessac, near Bordeaux, and Mousserolles substation, near Bayonne; similar cables of 95 mm<sup>2</sup> (0.147 sq. in.) section are employed between Mousserolles and Hendaye substations, and between Lamothe and La Teste substations on the Arcachon branch. The insulators are composed of 5 cap-and-pin type elements. There is no earthing cable.

#### *Traction substations.*

There are 40 substations on the Paris-Irun line, including one each for the Dourdan and Arcachon branches. The total length of line, including branches, is 867 km. (539 miles) giving an average substation spacing of about 21.5 km. (13.4 miles). This is reduced to 15 km. (9.3 miles) on the Paris suburban sections where the traffic is particularly dense, and increased to 24.5 km. (15.2 miles) on the last section, from Tours to Bordeaux, where there are 14 substations in 347 km. (215.6 miles). The main details of these substations are given in Table III.

The connection of the substations to the feeder system is either of the tee-off or series type; in the latter case the substation then forms a sectioning point. The high-tension gear is of the outdoor type (fig. 7).

The substation capacities are proportional to the type and importance of the traffic to be handled. They vary from 8 000 kW. in the Paris suburbs to 4 000 kW. between Orléans and Bordeaux; certain substations between Bordeaux and Irun have outputs as low as 2 000 kW.

The converting machinery is of three types; 750-volt rotary converters in series; 1 500-volt rotaries, and 1 500-volt mercury-vapour rectifiers.

750-volt rotaries in series are installed in 23 substations, i.e., all those between Paris and Angoulême, except on the

TABLE III. — Particulars of traction substations on the Paris-Irun line.

| Substation.                          | H. T. supply voltage. | Method of connection. | Converter sets. |                  |         | Substation capacity. | Method of control. |
|--------------------------------------|-----------------------|-----------------------|-----------------|------------------|---------|----------------------|--------------------|
|                                      |                       |                       | Number.         | Type.            | Rating. |                      |                    |
|                                      | kV.                   | (1)                   |                 | (2)              | kW.     | kW.                  | (3)                |
| Quai de la Gare (Paris) . . . . .    | 15                    | T                     | 4               | 2 C 750 volts.   | 2 000   | 8 000                | M                  |
| La Plaine . . . . .                  | »                     | T                     | 4               | »                | »       | 8 000                | »                  |
| Les Saugées . . . . .                | 90                    | T                     | 3               | »                | »       | 6 000                | »                  |
| Bellevue . . . . .                   | »                     | S                     | 3               | »                | »       | 6 000                | »                  |
| Saint-Evrault (Dourdan) . . . . .    | »                     | T                     | 2               | 1 R 1 500 volts. | 1 500   | 3 000                | A                  |
| Thionville . . . . .                 | »                     | T                     | 2               | 2 C 750 volts.   | 2 000   | 4 000                | M                  |
| Thivernon . . . . .                  | »                     | S                     | 2               | »                | »       | 4 000                | A                  |
| Saran (Orléans Nord) . . . . .       | »                     | T                     | 3               | »                | »       | 6 000                | A                  |
| Les Courelles (Orléans O.) . . . . . | »                     | T (4)                 | 2               | »                | »       | 4 000                | A                  |
| Les Gribouzy . . . . .               | »                     | T                     | »               | »                | »       | »                    | »                  |
| Les Vallées (Blois) . . . . .        | »                     | S                     | »               | »                | »       | »                    | »                  |
| La Commanderie . . . . .             | »                     | T                     | »               | »                | »       | »                    | »                  |
| Les Epines fortes (Tours) . . . . .  | »                     | S                     | »               | »                | »       | »                    | »                  |
| La Godinière . . . . .               | »                     | T                     | »               | »                | »       | »                    | »                  |
| Colombiers . . . . .                 | »                     | S                     | »               | »                | »       | »                    | »                  |
| Le Prieuré (Châtellerauld) . . . . . | »                     | T                     | »               | »                | »       | »                    | »                  |
| Chaumont (Poitiers) . . . . .        | »                     | S                     | »               | »                | »       | »                    | »                  |
| La Planche . . . . .                 | »                     | T                     | »               | »                | »       | »                    | »                  |
| La Cour . . . . .                    | »                     | S                     | »               | »                | »       | »                    | »                  |
| Longchamps . . . . .                 | »                     | T                     | »               | »                | »       | »                    | »                  |
| Le Palant . . . . .                  | »                     | S                     | »               | »                | »       | »                    | »                  |
| Rabion (Angoulême) . . . . .         | »                     | T (5)                 | »               | »                | »       | »                    | »                  |
| Chavenat . . . . .                   | »                     | S                     | »               | »                | »       | »                    | »                  |
| Courtillière . . . . .               | »                     | T                     | 2               | 1 R 1 500 volts. | 2 000   | 4 000                | A                  |
| Bessanges . . . . .                  | »                     | S                     | »               | »                | »       | »                    | »                  |
| Pomerol (Libourne) . . . . .         | »                     | T                     | »               | »                | »       | »                    | »                  |
| Moulinotte . . . . .                 | »                     | S                     | »               | »                | »       | »                    | »                  |
| La Médoquine (Bordeaux) . . . . .    | 60                    | T (6)                 | 3               | 1 C 1 500 volts. | 1 000   | 3 000                | M                  |
| Croix d'Hins . . . . .               | »                     | T                     | 2               | »                | »       | 2 000                | »                  |
| Lamothe . . . . .                    | »                     | S                     | 3               | »                | »       | 3 000                | »                  |
| La Teste (Arcachon) . . . . .        | »                     | T                     | 2               | »                | »       | 2 000                | »                  |
| Licaugas . . . . .                   | »                     | T                     | 2               | 1 R 1 500 volts. | 1 500   | 3 000                | A                  |
| Labouheyre . . . . .                 | »                     | S                     | 2               | 1 C 1 500 volts. | 1 000   | 2 000                | M                  |
| Morceux . . . . .                    | »                     | S                     | 3               | »                | »       | 3 000                | »                  |
| Cougnala . . . . .                   | »                     | T                     | 2               | 1 R 1 500 volts. | 1 500   | 3 000                | A                  |
| Dax . . . . .                        | »                     | S                     | 3               | 2 C 750 volts.   | 1 500   | 4 500                | M                  |
| Saint-Vincent . . . . .              | »                     | T                     | 2               | 1 C 1 500 volts. | 1 000   | 2 000                | M                  |
| Mousserolles (Bayonne) . . . . .     | »                     | S                     | 3               | »                | »       | 3 000                | »                  |
| Saint-Jean-de-Luz . . . . .          | »                     | T                     | 2               | »                | »       | 2 000                | »                  |
| Hendaye . . . . .                    | »                     | T                     | 2               | »                | »       | 2 000                | »                  |

(1) T = tee-off type. — S = series sectioning type.

(2) C = rotary converter. — R = rectifier.

(3) M = manual. — A = automatic.

(4) Between Saran and Les Courelles, the 90-kV. lines are sectionalized at Chaingy transforming station, near Orléans.

(5) Between Le Palant and Rabion, the 90-kV. line is sectionalized at Fléac transforming station, near Angoulême.

(6) Near La Médoquine, the 90-kV. lines are linked up through the Pessac transforming station, near Bordeaux.



Fig. 7. — View of 90-kV. outdoor equipment at Bessanges rectifier station, sectionalizing type.

Dourdan branch and in the Dax substation. They have a high efficiency (96 %) and a compound characteristic to prevent the voltage drop from becoming too great on heavy loads. They are of 2 000 kW. capacity, except at Dax, where the output is only 1 500 kW.

The 1 500-volt rotaries are installed in the ten substations between Bordeaux and Irun. The advantage of these lies in the fact that they take up less room than the series-connected 750-volt type, and require less equipment. On the other hand, they are of less robust construc-



Fig. 8. — Interior view of Moulinotte rectifier substation, showing on left the control board and on right the rectifiers behind their protective screens.

tion, and their output has up to the present been limited to 1 000 kW.

Mercury-vapor rectifiers are used in seven substations, four of which between Angoulême and Bordeaux (fig. 8). They possess the advantage of having no rotating parts and of being of very high efficiency (98 %), a figure which varies only slightly with load. They are of 2 000-kV. capacity on the Angoulême-Bordeaux section; the remainder are of 1 500-kW. output. The former are equipped with polarised grids for voltage regulation, and provide automatic compensation for voltage fluctuations in the A. C. supply.

All converting machinery is capable of withstanding 50 % overload for two hours, and 200 % for five minutes.

The majority of the older substations are manually controlled. In the more recent, between Orléans and Bordeaux, and in some of the older type which have been modified, automatic working has been applied to the starting up and shutting down of the converters, and also to the control and isolation of the 1 500-volt out-going feeders.

#### *Contact lines.*

These are of the overhead catenary type, but the method of suspension on the Paris and Bordeaux section is different from that on the Bordeaux-Irun line, for the Orléans Company has adopted the flat, semi-rigid catenary, with twin contact wires, whereas the Midi prefers a flexible catenary, with inclination on curves, and a single contact wire, which affords the maximum of flexibility.

The Orléans catenary is composed of a bronze main carrier cable of 116-mm<sup>2</sup> (0.18 sq. in.) section, a copper auxiliary carrier of 104-mm<sup>2</sup> (0.16 sq. in.) section, and two 107-mm<sup>2</sup> (0.166 sq. in.) contact wires, also of copper. The auxiliary carrier is suspended from the main carrier by round droppers spaced 4.50 m. (14 ft. 9 in.) apart; the two contact

wires are secured to the auxiliary carrier by sliding droppers 20 cm. (7 7/8 in.) long at intervals of 2.25 m. (7 ft. 4 1/2 in.), attached to each wire alternately. The catenary is maintained in the vertical plane on curves as well as on straight track by pull-offs.

The Midi type employs a steel main carrier cable of 79-mm<sup>2</sup> (0.123 sq. in.) section, a 100-mm<sup>2</sup> (0.155 sq. in.) copper auxiliary carrier and a 150-mm<sup>2</sup> (0.2325 sq. in.) contact wire, also of copper. The auxiliary carrier is suspended from the main carrier by rigid droppers free to slide vertically on the latter and spaced 9 m. (29 ft. 6 in.) apart: the contact wire is secured to the auxiliary carrier by means of clips. This method of construction provides a very flexible contact system. On straight track the catenary is kept vertical by stiffening hangers to prevent swing, but on curves these are dispensed with and the catenary is free to take its own inclination according to the tension in the contact wire.

On sections with very heavy traffic the catenaries are completed by feeder cables. On the Orléans System these are carried on the same insulators as the catenaries; on the Midi independent insulators are used, mounted on the same supports.

On branch lines catenaries of a simplified type are used without an auxiliary carrier and with only one contact wire. In places even the catenary is dispensed with and the contact wire is mounted on simple devices resembling the tramway type.

The overhead system is supported on the Paris-Orléans section by rigid structures spanning four or two tracks; between Orléans and Bordeaux it is carried on separate masts (fig. 10), spaced 63 m. (68.9 yards) apart on straight track, which enable the tracks to be kept mechanically independent of each other. Between Bordeaux and Irun « Gothic arch » structures (fig. 9) are employed,

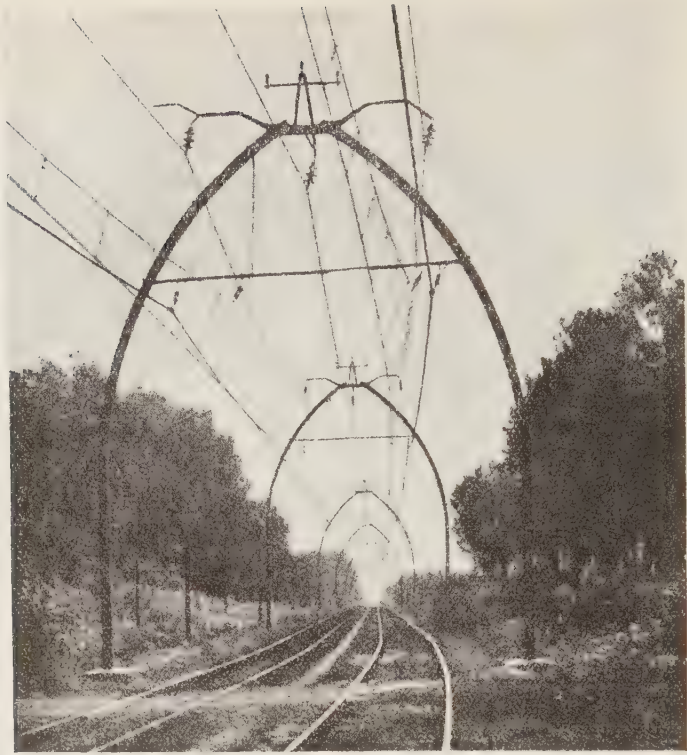


Fig. 9. — Track equipment on the Bordeaux-Irun line, showing « Gothic arch » structures which support the 60-kV. substation supply line in addition to the catenaries and feeder cables.



Fig. 10. — Track equipment on the Orléans-Bordeaux line, with individual masts and brackets, rendering each track mechanically independent of the other.

at intervals of 90 m. (98.4 yards), which also carry the 60-kV. line supplying the traction substations.

In the principal stations it was necessary to use structures with very wide spans and guyed masts, or with a cross-girder construction. On recently completed installations, between Orléans and Bordeaux, semi-rigid structures have been adopted with double catenaries, capable of withstanding considerable differences in load distribution without excessive deformation. Finally, on branch lines, support is provided by flexible structures composed of a carrier cable and a horizontal transverse cable from which the contact wire is suspended.

In order to localise breakdowns, simplify the finding of faults and facilitate operation and maintenance, the contact wires are sectioned at a number of points, especially in line with each substation, and divided up into stretches of about 4 km. (2.5 miles) in length; the sectioning points are of the long-overlap type and may be crossed at speed. On the Orléans system contact line sectioning and paralleling cabins are provided approximately midway between

substations: the circuit-breakers in the sectioning cabin and substation feeding the same section of line are operated in synchronism by means of a 1500-volt pilot wire running beside the track.

#### *Rolling stock.*

The locomotives used for hauling trains on this line are of two types:

1. 2 D 2 locomotives (fig. 1) for hauling express trains. These have a steel body supported at the centre on four independent driving axles, and at each end on a carrying and guiding bogie. Their horse-power is about 4000, and they are capable of a speed of 150 km. (93 miles) an hour.

2. B B locomotives for stopping passenger trains and goods trains. These machines comprise a steel body carried on two bogies, each with two independent driving axles; the horse-power varies from 1200 to 1500 H.P. and the speeds from 90 to 100 km. (56 to 62 miles) an hour.

For this last section of the electrification of the Paris-Irun line (Tours-Bordeaux section), 16 new 2 D 2 and 24 new B B locomotives have been ordered.

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[ 621. 59 & 669. 1 ]

## Surface hardening of steel cylindrical parts by means of high-frequency currents

by the late Dr. Ing. Heinrich HAIDUK,

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(From *Glaser's Annalen.*)

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Surface hardening is a process used to make heavily stressed parts wear resisting without appreciably lowering their mechanical properties. It actually consists in an alteration of the surface of the treated part, leaving the interior unaffected.

The best known method of surface hardening is case hardening: the part

to be hardened, which owing to its chemical composition cannot be hardened directly by quenching, is embedded in certain materials and submitted in this state to heat treatment, the effect of which is gradually to alter its texture, starting from the surface, by absorption of carbon, so that these superficial zones - and these only - thus enriched in

carbon, become capable of being hardened. The depth of the alteration in texture depends on the time the heat treatment lasts — several hours for great depths.

Surface hardening, however, can also be carried out by the usual heat treatment when it is found possible to heat, to the required temperature, only the superficial layers of the article to be treated, all other portions of it remaining at a lower temperature. This is feasible when the quantities of heat applied to the detail are large enough to produce a sufficient difference between the temperature of the surface and that inside. If the part is quenched with such a temperature distribution, all the zones the temperature of which was before quenching higher than the critical temperature, will be hardened, whereas all other zones will remain mild.

The difference in the surface temperature and that inside, necessary for surface hardening, can be obtained, for instance, by means of a welding flame; this process is already much resorted to. As the part to be dealt with cannot generally be treated wholly at one and the same time, the flame is moved relatively to the part and applied to the whole surface bit by bit. Each spot is heated to the required temperature and quenched immediately thereafter. If the (cylindrical) part to be hardened is made to revolve while the flame and quenching jet move axially, the surface is hardened along a helical path. The great advantage of this process — and of that by means of high-frequency currents, described in this note — over case hardening is the exceptionally large time saving. As a matter of fact, the time required for hardening is reduced to a few minutes, or even seconds, depending on the size of the article. It is true that with the flame the depth of the hardened zone has an upper limit as we shall see later.

Surface hardening by means of high-frequency currents is based on the fact that, in conductors through which altern-

ating current is caused to flow, the current density is far from being uniformly distributed between all the portions of the cross section of the conductor, as is the case with direct current. With conductors through which a current flows directly, this phenomenon, known as skin effect, results in increased resistance, the latter growing as the frequency rises. The reason is that in the cross section the current is — figuratively speaking — forced to the surface, whence a reduction of the effective cross section.

The principle will be grasped when one imagines the (cylindrical) conductor as being divided into a certain number of concentric hollow cylinders. Each of these hollow cylinders has an ohmic resistance and an inductive resistance. According to well known laws, the ohmic resistance gives rise to a uniform current intensity in the whole of the cross section. Such is not the case with the inductive resistance. The latter is a maximum in the smallest hollow cylinder and a minimum in the outer one; in fact, it is directly proportional to the number of lines of force connected with the conductor under consideration, and this number, which is a maximum in the innermost hollow cylinder, diminishes as the hollow cylinder is located further away from the centre line.

Now, for a given voltage, the current always seeks the path of least resistance and consequently it will flow preferably in the surface. It is clear that the magnitude of this current deviation will be in proportion to the frequency and the magnetic conductivity of the conductor, seeing that the inductive portions of the resistance then become of growing importance.

On the other hand, this magnitude will decrease in proportion as the resistivity increases because the ohmic portions of the resistance, which would require uniform distribution of the current, play a more important part.

If, consequently, a strong high-fre-

quency current were made to flow through a cylindrical conductor of this kind, the superficial zones would be more heated than the interior, and if the current were strong enough to cause heating up within such a short period that the heat applied had no time to spread to the interior, the temperature distribution suitable for surface hardening would be obtained.

It will be seen that surface hardening by means of high-frequency currents is governed by two factors: current frequency and intensity. The former governs the depth of the superficial zone heated, the latter the degree of equilibrium of the temperature.

The frequency should be so selected that only the zone to be hardened be heated; on the other hand, the current should be strong enough for the heating to occur within such a short period that the heat is unable to spread from these heated layers to the interior zones.

If, for instance, it were desired to surface-harden, in the way described above, a locomotive coupling rod crank-pin by direct passage of the current, it would be necessary to use current of about  $10^5$  amperes, with a tension of about 1 volt.

The difficulties arising can be evaded by applying the current not directly, but indirectly to the part to be hardened. To this end the part may be lodged inside a coil through which a high-frequency current is caused to flow. The magnetic field of the coil then induces in this core currents which also flow mainly through the surface, physically for another reason than previously, it is true.

If the cylindrical core is imagined as being divided into a number of hollow cylinders, the magnetic field of the exciting coil will induce in each hollow cylinder an annular voltage which will give rise therein to a current in the indicated direction. According to well known electro-technic rules, this current

is opposed to that of the exciting coil. In its turn it creates a magnetic field which is consequently opposed to the initial field from the exciting coil. The effective magnetic field is thus weakened progressively by the currents in the core, towards the centre, with the result that the voltage created in the different hollow cylinders becomes the weaker the nearer to the centre the hollow cylinder is located — the current being weakened simultaneously — because the voltage is directly proportional to the total magnetic flux surrounded by the hollow cylinder.

Precise calculations show that the current density decreases from the surface of the core towards its interior according to a function  $n$ . The distance beyond which the current density no longer exceeds the  $n$ -th part of its value at the surface is called the « penetration depth ». It is calculated by means of the formula

$$\delta_{mm} = 500 \sqrt{\frac{\rho}{\mu \times f}}$$

where

$\rho$  = the specific resistance of the core,  
 $\mu$  = the magnetic conductivity of the core,

$f$  = the frequency of the exciting current.

This distance is, in the case of copper, for instance, with a frequency of 1 000 cycles,

$$\delta = 500 \sqrt{\frac{0.018}{1 \times 1\,000}} = 2.1 \text{ mm } (0.0826 \text{ in.}).$$

It will be realised that the penetration depth must increase when the resistivity increases, and diminish when the frequency rises. The values of  $\rho$  and  $\mu$  for a given material are known. The frequency of the exciting current can be selected at will; it varies, of course, in each particular case.

The chief difference between electric surface hardening and gas hardening

consists in that, with the former, a certain superficial layer is heated directly, whereas with the latter the heat is applied directly to the surface only. This means that, with gas hardening, the inside temperature distribution is governed by the exponential drop due to the properties of the material, the superficial temperature, and the time the treatment lasts, which drop can be calculated by means of these data.

Now, the superficial temperature has an upper limit beyond which the surface will burn; the hardening temperature is a fixed one and moreover, for metallurgical reasons, the temperature at the inner edge of the hardened zone has a lower limit. The maximum possible hardening depth can thus be calculated, and is, moreover, independent from the outside dimensions of the part to be hardened.

With high-frequency surface hardening, conditions are different; in this case the heat is not applied to the surface, but created in the outer layers of the article to be hardened, it being possible, moreover, to regulate the depth of these layers between wide limits by selection of the frequency. The heat generated immediately on the surface would have by itself a temperature distribution similar to that of gas hardening, i.e. decreasing exponentially towards the interior. To this, however, must still be added the quantities of heat created in the other layers. The temperature of the latter corresponds more closely with that of the points in question the larger they are, i.e. to a high proportion near the surface, and a very small one inside. Consequently a particularly favourable temperature distribution for surface hardening exists, seeing that the layer to be hardened is heated much more uniformly, though the temperature drop, starting from the surface, is sharp. The situation is still improved by the fact that with this temperature gradation, the current density completely ceases to decrease exponentially, the resistivity vary-

ing much from one location to another; the resistivity is high at the surface (owing to the high temperature), and low inside. As the resistivity is a factor in the formula for the penetration depth, this means that this depth is great at the surface and small in the more inner layers.

In the case of iron, with which the magnetic conductivity, which also appears — inversely, it is true — in the penetration depth formula, is markedly lower at the surface than in the deep seated layers, owing to the reduction of the magnetic field towards the centre, this effect is still more accentuated. In this way the ideal case — uniform and direct heating of the layer to be hardened, and of this layer only — is approached.

In practice, surface hardening by high-frequency currents is an easy matter from the technical point of view. The cylinder whose surface is to be hardened is lodged in the field coil, and alternating current is caused to flow through the coil. As surface hardening, as mentioned previously, requires high power, the feed lasts only a few seconds, according to the dimensions of the detail to be hardened. Difficulties arise when the latter has portions which cannot be introduced into the coil (crankpin bearings). In this case the coil is made pincer shaped and articulated. Owing to the conditions as regards passage of the current at the separation line, it is then made up of only one winding, which necessitates exceptionally strong current, say of about 10<sup>4</sup> amperes. The exciting frequency depends on the size of the part treated. It must be the higher the smaller the part. Its lower limit is determined by the condition that the penetration depth may at most be equal to 1/4 of the diameter, as otherwise the transmission efficiency becomes very low.

As the coil, owing to its inductivity, absorbs a large quantity of wattless power, the power factor measured in it is

very small, its value being about  $\cos \varphi = 0.2$ . Consequently it is necessary to compensate for this wattless power by suitable condensers, in order to relieve therefrom the high-frequency generating machine. According to the type of the latter, the condensers are connected in parallel or in series with the coil. The first arrangement is selected for operation with high-frequency machines, because the latter only have to supply the effective power at a voltage equal to the total voltage in the coil. The second arrangement is used with rectifiers re-

quiring such wiring. The rectifier then has to supply the whole of the current flowing through the transmission device, at a voltage equal only to the effective part of the voltage in the coil. With the high-frequency machine and coil, frequencies of about 10 000 cycles are obtainable. If still higher frequencies are required for treating very small parts, recourse has to be had to high-vacuum valves, which will provide sufficiently high frequencies for any case that may arise.

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[ 625. 244 (.75) ]

## American refrigerator wagons

by Reichsbahnrat Helmut BAUR, WVV, Berlin.

(From *Verkehrstechnische Woche*.)

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Most of the industrial centres and the densest areas of population on the North American continent are in the north-east. On the other hand, the chief centres of production of fruit and vegetables are located in the south and west and the principal centre of the meat products industry is Chicago, in the « Middle West ». This geographical distribution of the centres of production and consumption of perishable foodstuffs gives rise to a very heavy traffic in conveying them from the south-eastern states, on the one hand, and from California and the Middle West on the other, to the large cities of the north-east. To this traffic is added short-distance fresh fish traffic along the coast and dairy produce from the milk production areas around the large towns in the east, as well as the transport of eggs. The rapid growth of population in the east has necessitated the adoption

of suitable means of transport and gave rise in America, more than half a century ago, to the creation of the railway refrigerator wagon.

The wide extent of the perishable foodstuff traffic has necessitated the putting in service of a park of refrigerator wagons capable of meeting all demands; at present this comprises about 160 000 vehicles of which 26 000 belong to the railway companies, while the others are owned by large refrigerator wagon companies, shippers of fruit and vegetables, meat products companies and other private concerns.

### 1. The standard refrigerator wagon.

The development of the construction of refrigerator wagons culminated about 20 years ago in the vehicle known as the standard. This does not represent any normal official design, but its

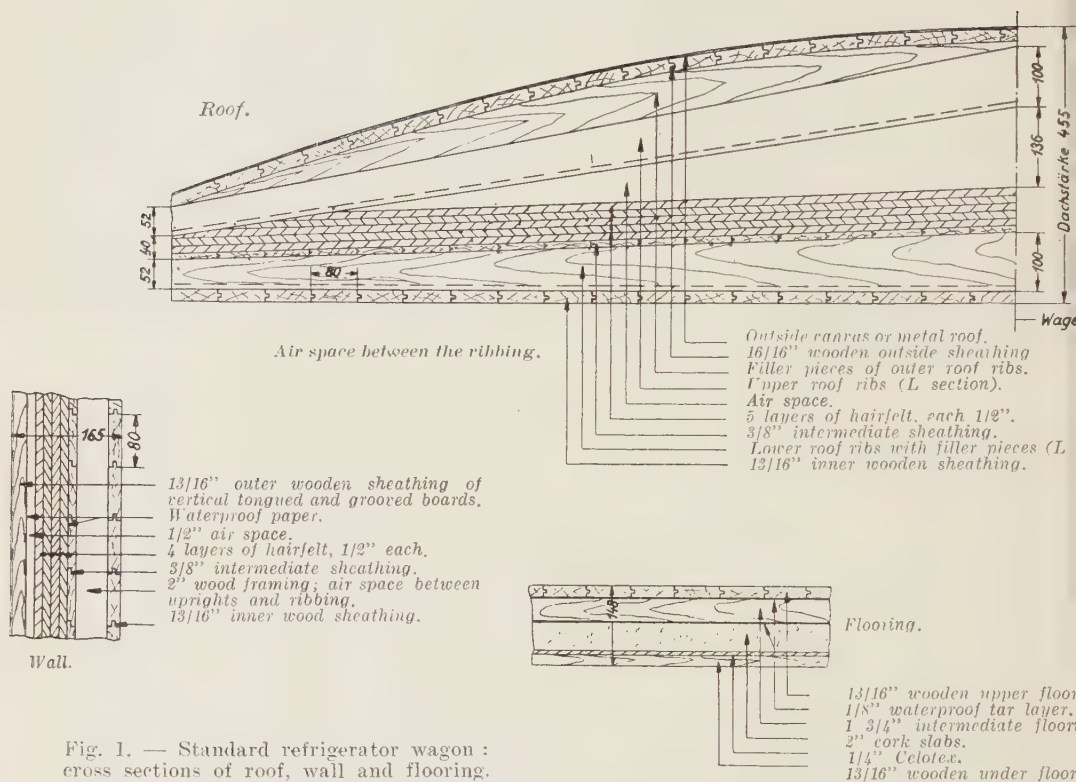


Fig. 1. — Standard refrigerator wagon : cross sections of roof, wall and flooring.

*Note.* — Dachstärke 455 = thickness of roofing, 15 1/2". — Wagenmitte = centre line of wagon.

essential characteristics were put forward as a general guide by the chief Government inspecting authorities and the Association of American Railroads. For this reason, the rolling stock belonging to the various owners of refrigerator wagons presents certain differences in matters of detail, such as the nature of the heat insulating material used.

The standard refrigerator wagon comprises a steel underframe with wooden body. As with all American railway vehicles, especially all the goods wagons, the standard refrigerator wagon is carried on bogies. A certain number

are equipped with passenger carriage bogies, to enable them to run in passenger trains. The underframe does not differ from that of other goods wagons; it is formed of two central longitudinal members, with bracketed cross bearers, connected by sole bars joining them in turn to the headstocks. The ends of the central longitudinals contain the draw and buffing gear of the central coupler.

The floor joists of the wooden framing of the body are secured to the steel underframe by bolts. The side walls, formed of stanchions and transoms, are covered outside with vertical tongued

and grooved boarding, as shown in Fig. 1 (1), which gives the construction of the walls, roof and floor. The lateral external panels are lined on their inner faces with waterproof paper. Then comes an air space, four layers of horsehair felt, another layer of waterproof paper and finally a further intermediate wall which rests directly on the body framing. The spaces between the frame elements are left empty and serve as insulating air spaces. The other face of the framing carries the inside panelling, of horizontal tongued and grooved boards. The overall thickness of the wall is 165 mm. (6 1/2 in.).

The floor is of triple formation; the intermediate flooring is covered on both faces with waterproof paper. Between it and the lower one are layers of cork and Celotex boards (see below). The overall thickness of the triple floor is 148 mm. (5 13/16 in.). The covering over the interior of the wagon is supported by the steel lower roof ribs with wood packing. An intermediate covering acting as a support to the five layers of horsehair felt, bears against the roof ribs. Then come the upper roof ribs, also of steel, the wooden packing of which is covered by the outer roofing and its tarpaulin covering. The last named is often replaced by a sheet metal one. The spaces between the roof ribs are left empty.

The method of constructing the walls and flooring shows a clear intention of protecting the heat insulating material against moisture coming from the interior of the wagon. This desirable object has been obtained in the walls by arranging the empty spaces of the fram-

ing between the actual interior of the wagon and the insulating material, as well as the intermediate panelling and the layer of paper, and, in the lower portion, the intermediate flooring and two layers of paper. The wooden portions of the refrigerator wagons are treated antiseptically by injecting creosote or some similar product.

The doors of refrigerator wagons having wooden bodies are also of wood and fitted with the same heat insulating material as the walls. The reciprocal tightness of the two portions of the double-leafed doors is effected by means of a cover plate strip attached to one of the leaves, packed with horsehair felt and covered with waterproof sheeting (spring board). As shown in Fig. 2,

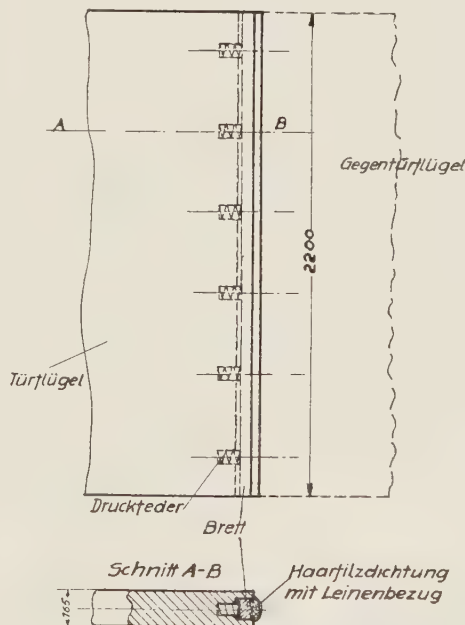


Fig. 2. — Sealing of door by means of spring loaded packing piece (« springboard »).

Explanation of German terms :

Gegentürflügel = companion door leaf. — Türflügel = door leaf. — Druckfeder = compression spring. — Brett = lath. — Schnitt A B = section A B. — Haarfilzdichtung mit Leinenbezug = hairfelt packing with canvas cloth covering.

(1) Figs. 4, 11, 12 have been kindly placed at the Author's disposal by the *General American Tank Car Co.*, of Chicago, Ill.; Fig. 7 by the *Pennsylvania Railroad*, Philadelphia, Pa.; Figs. 8 and 9 by the *Safety Refrigeration Inc.*, New York, N. Y., and Fig. 10 by the *North American Car Co.*, Chicago.

when the door has been closed, this elastic strip presses against the frame of the other door leaf, forming an airtight joint therewith. Each leaf is insulated in like manner from its frame post, the strips forming the joints being housed in the uprights. A similar strip, on the upper cross-member of the door frame, likewise forms a joint at the top edges of the doors. As the same device cannot be employed at the bottom of the door, the lower edges of the leaves are fitted inside with a double lap joint of pleated canvas which, when the door is closed, presses against a return edge on the entrance floor.

The door securing device (Miner type) used in the great majority of cases is shown in Fig. 3. It consists of two cast

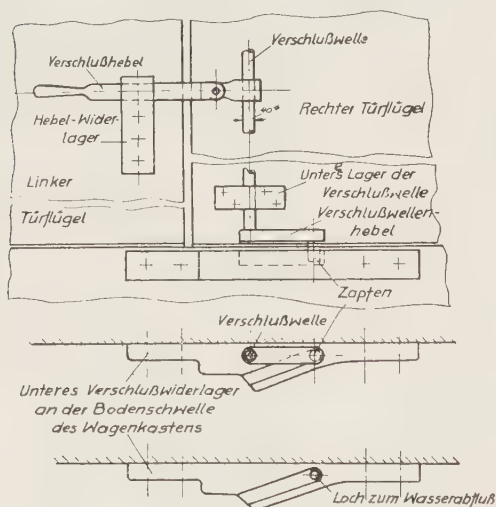


Fig. 3. — Standard refrigerator wagon door lock.

*Explanation of German terms :*

Hebelwiderlager = handle securing rest. — Linker (rechter) Türflügel = left (right) door leaf. — Loch zum Wasserabfluss = water drain hole. — Unteres Lager der Verschlusswelle = lower locking spindle bearing. — Unteres Verschlusswiderlager an der Bodenschwelle des Wagenkastens = lower locking counter-bearing on the floor beam of the body frame. — Verschlusshebel = locking handle. — Verschlusswelle = locking spindle. — Verschlusswellerhebel = locking spindle handle. — Zapfen = pin.

iron steps, cut away in bevel fashion, fixed on the upper and lower sole bars

of the body framing. One of the door leaves carries, in three bearings, a vertical locking shaft. The latter carries, top and bottom, locking spindle arms with studs which engage in the sloping recesses or notches of the stop pieces when, on closing the door, the locking spindle is rotated by means of the operating handle. This causes the centre line of rotation of the one-armed lever system — represented by the centre line of the studs on the locking spindle arm — to come against the end of the sloping notches in the locking stop. Under this wedge-shaped action the door leaves are pressed tightly against the packing pieces. The locking handle, which turns in a vertical plane, is pressed down at the end of the locking operation and engages with a Z-shaped retaining stop. A hole in the recess in the bottom locking stop allows water to escape. The American door fastener is analogous, in principle, to that used on the German refrigerator wagons recently built (2). However, on the latter the oblique wedge face which produces the fastening effect is arranged in two pieces, in hook-shaped form, placed at the upper and lower ends of the securing bar. These hooks move, during the act of closing, behind pins placed on the upper and lower longitudinal members of the body framework. The German device would appear to offer greater advantages in that foreign objects cannot lodge in the securing mechanism, while they can do so in the sloping notches of the stops in the American device, rendering it difficult to manipulate.

The ice chambers are separated from the space used for goods, at each end of the vehicle, by transverse partitions, extending from 350 mm. (13 3/4 in.) above the floor to 425 mm. (16 3/4 in.) below the roof. In a certain number of wagons the partitions come down to the

(2) See *Organ*, 1935, No. 21, 1st November : TASCHINGER, Kühlwagen für Fährbootverkehr nach England (Refrigerator wagons for the English train ferry service).

upper edge of the wooden floor grating with the double object of distributing the cold air as evenly as possible under the floor bars (see below) and to protect against the load being affected by splashes from melting ice and the parts of it adjacent to the ice chambers from becoming frozen, when freezing mixtures are used. The double covering of a transverse partition contains a layer of heat insulating material from 25 to 60 mm. (1 to 2 3/8 in.) thick with, sometimes, an air space. As the stock of ice is renewed through the roof of the vehicle (see below), the transverse partitions of the ice chambers have no doors as a rule. The ice chamber itself is formed, in all wagons built recently, of galvanised steel angle irons and a stout steel lattice work (basket bunker); it is placed at a distance of about 60 mm. (2 3/8 in.) from the walls surrounding it, in order to maintain a sufficient passage for the circulation of the air and facilitate the transfer of heat between the air and the ice. To increase still further the surface of the ice in contact with the air, the ice chambers are sometimes divided into two or more elements. It is only in old wagons that the chambers are formed simply by heat insulating them at the ends of the vehicles, without using the above mentioned steel items (plain bunker). In a certain number of wagons, the ice supports may be found placed half way up the chambers, in order to guard from an excessive loss of heat by radiation such products as must not be chilled below a pre-determined temperature and which happen to be stowed in the immediate vicinity of the lower ice chamber opening; this arrangement is more especially used for banana traffic. In addition the column of air issuing from beneath the ice holder being larger, the circulation of air in the vehicle is promoted. When it is required to obtain lower temperatures than are possible with ice made from pure water or water with salt added, then the ice chambers are replaced by

galvanised steel brine troughs (brine tanks) filled with special freezing mixtures of finely broken ice and saline mixtures. There are usually four brine troughs in the ice chamber at each end of the wagon. The ice gratings in the ice tanks — bars of wood or, in newer wagons, of V shaped galvanised stamped sheet metal, point upwards — and the platform carrying the brine troughs are about 300 mm. (11 3/4 in.) above floor level.

The ice containers and brine troughs are always recharged through the roof of the wagon through *manholes* at each end. There are generally two at each end of the roof. The wooden hatch covers of the manholes, with heat insulating material attached, have a hair-felt joint round their circumference, set in a recess in the frame and covered with impregnated waterproof canvas cloth. The footway arranged the whole length of the roof for the operation of the hand brakes, and to permit the staff of a goods train to go from one end of it to the other, is available also for the constant and easy replenishment of the ice in the refrigerator wagons on an entire train.

Under the ice chambers the flooring is deepened and provided with bituminised waterproof paper, coated with a thick layer of tar, to catch water dripping from the melting ice. In the middle of the recess so formed, all parts sloping to this point, is the *discharge opening* for this water, fitted with a cut-off cock attachment, the upper part of which can be lifted up to allow of the device being cleaned. Its construction is similar in principle to that used in Germany, but the method of closing by means of an indiarubber ball, provided on the new German wagons when used without ice, does not exist in the United States. The American refrigerator wagons have simply discharge hoppers under the ice chambers; the floor slopes towards the discharge vents from the centre of the vehicle to the two ends. The brine

troughs are connected together above their bottoms by pipework which goes down through the floor and serves as a discharge for the warm brine; it is fitted with a valve loaded by a weight, which can be opened from the roof by a pull rod. The constant leaking away of the warm brine, such as is regular practice today for the water from the ice-cooled refrigerator wagons, is prohibited on account of the chemical action of the brine on bridges and track. Water and brine escaping from the discharge pipe are led by a channel or gutterway to the outside of the wagon to prevent any salt liquid getting on the bogie.

The standard refrigerator wagon has no devices for *stimulating air circulation*. Between the ice chambers and the space reserved for conveying goods, this circulation is assured simply by the differences in specific weight of the cold air issuing from the bottom of the ice chambers and the internal air warmed by the heat of the goods being carried and by heat transmitted from outside. In the distribution of the cold air throughout the whole length of the goods space an important part is played by the wooden floor grills used in nearly all American refrigerator wagons. Between the lower laths, parallel to the sides of the vehicle, the cold air can spread under the goods, to rise after that between the laths placed transversely. The grills are divided in sections along the longitudinal axis of the wagon and can be lifted and hooked to the sides of the body. The centre panels of the grill, alongside the doors, can be withdrawn from the wagon or are connected by hinges to the adjacent panels. The refrigerator wagons can thus be used at will with or without floor grills, while the practical arrangement of the latter allows the floor to be cleaned easily. In refrigerator wagons allocated to parcels traffic, such as cases of butter, margarine and eggs, stowed without leaving spaces

for the air to circulate, as in the case of the openwork boxes and casks used for fruit and vegetables, the side walls are likewise fitted with grills allowing the cold air to play round all parts of the load. To reinforce this action many shippers also fit intermediate grills, both vertical and horizontal, between the different rows and piles of boxes. In a certain number of refrigerator wagons the side grills have been replaced by vertical laths nailed to the side walls. Comparative tests with and without grills have demonstrated their utility, notably that of the floor grills, in promoting speed of chilling and uniform temperatures throughout the goods conveyed.

The wagons known as « ventilated refrigerator cars » are arranged in a very simple manner to promote *circulation of fresh air*. By means of an adjustable pull rod the amount of opening of the traps in the roof communicating with the ice chambers can be regulated at will. The fresh air is caught by the forward trap, which opens against the draught produced by running, passes over the stock of ice in the ice chamber placed below the trap, traverses the load space in the wagon, and escapes by the outlet at the rear end. Sometimes the roof vents are surmounted by cowl tops in sheet metal, the air catching opening being fitted with a fine metal gauze to prevent, as far as possible, pieces of coal or other foreign bodies passing into the interior of the wagon. These air ventilated wagons are used for transporting different sorts of fruit; the approximate graduation of the temperature by means of the size of the trap openings allows of preventing the excessive cooling of the fruit and in particular the gradual raising of its temperature again towards the end of the journey, so that during unloading the water vapour in the warm external atmosphere will not condense on the surface of the fruit. In the spring and autumn such wagons are used as

simple ventilated ones, without any ice supply.

To permit of the load space in refrigerator wagons being better utilised for articles that cannot be piled up, such as milk churns, or fruit baskets liable to be injured by compression, certain wagons have intermediate grills or floors which, when not in use, are revolved on their hinges to rest against the side walls and secured by clamps. The intermediate floors rest on supports in the centre of the wagon, which can be lifted up through the floor grills.

In the German wagons the meat suspension hooks are arranged to slide on their carrying bars. In the United States, on the contrary, the meat suspension arrangements consist simply of bars ranged along the lateral walls carrying the actual transverse suspension bars on which the *movable* « S » hooks bearing the quarters of meat are placed.

We give below some *numerical particulars* concerning the standard refrigerating wagon :

The great majority of American refrigerator wagons are of standard dimensions. But there are others of smaller size, loading 22.5 t., 41.0 t. and 54.5 t. (22.1, 40.3 and 53.6 Engl. tons).

So far we have, when referring to the heat insulating material of the walls and the roof, spoken only of hairfelt, or hair-cloth, very frequently used, formed of cattle hairs lightly compressed. The reason advanced for giving preference to this product is that, in addition to its moderate price, the hairfelt in wagons sent into the repair shops with their insulating material affected by moisture is very easily put in order again. Several other such materials are also employed. Table I gives the specific weights and co-efficients of thermal conductivity of some frequently met with in service.

Alfol (aluminium foil) has so far been used only in isolated cases, apparently for commercial rather than technical reasons.

Under the pressure of high wages the

|   |   |
|---|---|
| Length, overall . . . . .   | 12.25 m. (40 ft.)   |
| Length of load space . . . . .  | 10.00 m. (33 ft.)   |
| Length of one ice chamber . . . . .   | 0.90 m. (3 ft. 11 1/2 in.)                                |
| Width inside . . . . .  | 2.50 m. (8 ft. 2 7/16 in.)                                |
| Height inside above the floor . . . . .   | 2.30 m. (7 ft. 6 9/16 in.)                                |
| Width of doors . . . . .  | 1.20 m. (4 ft.)   |
| Height of doors . . . . .   | 2.00 m. (6 ft. 6 3/4 in.)                                 |
| Distance between bogie centres . . . . .  | 9.25 m. (30 ft. 4 in.)                                    |
| Tare weight . . . . .   | 26 t. (25.6 Engl. tons)                                   |
| Normal load . . . . .   | 36 t. (35.4 Engl. tons)                                   |
| Capacity of ice chambers . . . . .  | 4 000 to 5 000 kgr.<br>(8 800 to 11 000 lb.)              |
| Tare per ton of normal load $\frac{26}{36} =$ . . . . .   | 0.72 ton.   |
| Tare per m <sup>3</sup> of useful load space $\frac{26}{11.8 \times 2.5 \times 2.3} = \frac{26 \text{ t.}}{68.3} =$ | 0.38 t./m <sup>3</sup><br>(0.0105 Engl. ton per cu. ft.). |
| Tare per m <sup>2</sup> of floor area $\frac{26}{11.8 \times 2.5} = \frac{26 \text{ t.}}{29.5} =$                   | 0.88 t./m <sup>2</sup> (0.0804 Engl. ton per sq. ft.).    |
| Tare per metre of outside length of wagon $\frac{26 \text{ t.}}{12.25} =$   | 2.12 t./m. (0.635 Engl. ton per ft.).                     |

TABLE 1.

| Name of the heat insulating material.   | Composition.   | Specific weight.<br>Kgr./m <sup>3</sup><br>( <i>Lb./cu. ft.</i> ) | Co-efficient of conduction<br>Kcal./m <sup>2</sup> /h./°C.<br>( <i>B.T.U./sq. ft./hr./°F.</i> ) |
|---|--|---|---|
| Hair felt . . . .                       | Lightly compressed cattle hair . . . .                           | 192.0 ( <i>120.0</i> )  | 0.033 ( <i>0.067</i> )  |
| Dry Zero (3) . .                        | Kapok fibre . . . . .  | 16.0 ( <i>10.0</i> )  | 0.030 ( <i>0.061</i> )  |
| Balsam wool . . .                       | Chemically treated wood fibre . . . .                            | 35.2 ( <i>22.0</i> )  | 0.034 ( <i>0.069</i> )  |
| Hairinsul . . . .                       | 75 % hair, 25 % jute . . . . .                                   | 99.2 ( <i>11.0</i> )  | 0.034 ( <i>0.069</i> )  |
| Rock wool . . . .                       | Mineral wool (similar to slag wool) . .                          | 240.2 ( <i>150.0</i> )  | 0.035 ( <i>0.071</i> )  |
| Glass wool . . . .                      | . . . . .  | 160.0 ( <i>100.0</i> )  | 0.036 ( <i>0.073</i> )  |
| Corkboard with asphaltic binder . . . . | Slabs of granulated cork with asphalt binding material . . . . . | 232.0 ( <i>145.0</i> )  | 0.040 ( <i>0.082</i> )  |
| Insulite . . . . .                      | Compressed wood fibre . . . . .                                  | 270.0 ( <i>168.5</i> )  | 0.043 ( <i>0.088</i> )  |
| Celotex . . . . .                       | Compressed sugar cane fibre . . . . .                            | 211.0 ( <i>132.0</i> )  | 0.043 ( <i>0.088</i> )  |

time required for the erection of Alfol insulated wagons is reduced by spreading the leaves flat in frames, corresponding to the dimensions of the framing panels of the wagon body, and setting them in the latter with hairfelt packing so as to leave no play. If, for example it is desired to use ten layers of alfol they are placed between eleven thin frames, generally of celotex, secured together by nails in one unit ready for mounting. Where these units with their layers of alfol are arranged horizontally, iron wire framings are spread between certain of them to prevent the sinking of the alfol sheets and their being knocked together by shock.

## 2. New types of refrigerator wagons.

### (a) Wagons for ice or brine refrigeration.

Until 1935, the standard wagon remained little altered from the form above described. As business again began to increase it became necessary to construct new wagons and a modification of the design was considered. Efforts were made to get a more airtight and lighter form of construction and, at the same time, to reduce costs of repairs. These gave rise, following a proposal advanced in common by all the American rail-

ways, drawn up by the Association of American Railroads (A. A. R.), to a *refrigerator wagon with steel body frame* and external panelling in steel sheet. The idea was entertained of constructing the wagon sides perfectly airtight, producing an excellent heat insulating effect, similar to that of the surround of a thermos flask, but this was given up, as too expensive. The new type of wagon, the outside of which is shown in Fig. 4, was ordered in a



Fig. 4. — New refrigerator wagon with steel framing and sheet steel outer panelling.

batch of 1 000, spread among various builders.

The leading dimensions of the all-steel and the standard refrigerator wagons are practically identical. The principle of the construction of the underframe of

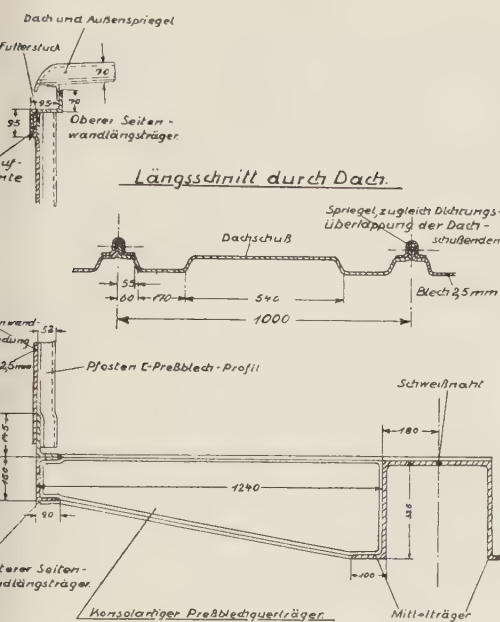


Fig. 5. — Refrigerator wagon with steel framing, outer panelling and roof. Constructional details.

*Explanation of German terms :*

Blech = sheet metal. — Dach und Außenspiegel = roof and outer ribbing. — Dachschräb = roof section. — Futterstück = filler piece. — Konsolartiger Preßblechquerträger = bracket shaped pressed plate cross member. — Längsschnitt durch Dach = longitudinal section through roof. — Oberer Seitenwandlängsträger = upper side wall longitudinal. — Pfosten = pillars. — Preßblechprofil = pressed plate section. — Seitenwandbekleidung = side wall covering. — Spiegel, zugleich Dichtungsüberlappung der Dachschüssenden = ribbing, forming also sealing overlapping of the ends of the roof sections. — Traufkante = dripping edge. — Unterer Seitenwandlängsträger = lower side wall longitudinal.

the latter has not been modified at all. The vertical members are riveted with the aid of angle irons to the U-longitudinals which join the bracket shaped end transverse members (Fig. 5). The side walls thus do not play any supporting part. The verticals consist of pressed U irons, channel outwards, the outer wall panels being riveted to their planed edges. The upper ends of the verticals are connected by a Z iron. Between the sheet panelling and the ver-

ticals are plate filler pieces, so that the upper wall bearing longitudinals project beyond the panelling and form a rain drip edge. The steel roof sections are corrugated, as shown in Fig. 5, to obtain greater rigidity, but their ends are flat to enable them to be riveted to the connecting angle irons of the upper longitudinal. The roof ribs are covered by pressed U irons, which also serve to secure the water tightness of the joints between the sections. These light pressed metal ribs, in combination with the corrugation of the roof sheets, give a sufficient degree of rigidity to the whole to make it unnecessary to provide the roof with a special framing under the outer skin. The outer end walls are, as in nearly all the closed goods wagons, of pressed sheet metal with stiffening corrugations (fig. 4). Each end plate is divided on its horizontal axis. To protect the roof and wall plates from corrosion 0.3 % of copper is added. Welding is but little employed in assembling the steel constructional parts of these wagons. Only the two Z's of the principal central longitudinals are welded together electrically (fig. 5); in addition, the door frames and the angle irons for attaching the ice chambers are similarly welded. The reason advanced for the small use of welding in assembling is the lack of skilled men to do it, the much greater difficulty with welding than with riveting of making sure that the work has been properly done, and the higher cost of welding. Stress is particularly laid on the fact that with the existing riveting equipment and trained workmen — frequently coloured men — working at a low figure, it is possible to rivet the joints, while for welding equipment capital must be first invested and the wages for welding are much higher with the present type of wagon construction. Welding will become more extensively used when the largest possible number of joints can be welded by means of automatic

appliances in the hands of skilled workmen.

The heat insulation of the walls, roof and floor is shown in Fig. 6. For the two first named, kapok fibre matting has been used, and hairfelt for the floor. The latter material has been used again on account of the advantage above-mentioned of being able to be restored to service conditions after being impregnated with moisture; the insulating material of the floor, of course, is particularly exposed to such risk. The interior panelling and the double flooring are in white pine, and the floor joists partly of oak. The floor is cover-

ed with a double layer of tarred paper which is said to give the best results from the point of view of watertightness. For additional protection against water, galvanised metal sheeting is placed between the flooring and the tarred paper under the ice chambers. The tarred paper is turned back against the floor cross members for a distance of 100 mm. (4 in.) so that moisture shall not penetrate between the floor and the covering of the side walls. As these wagons always have floor grills and the tarred paper is thus not subject to mechanical action, the latter can serve as upper floor covering. The bolts connecting the

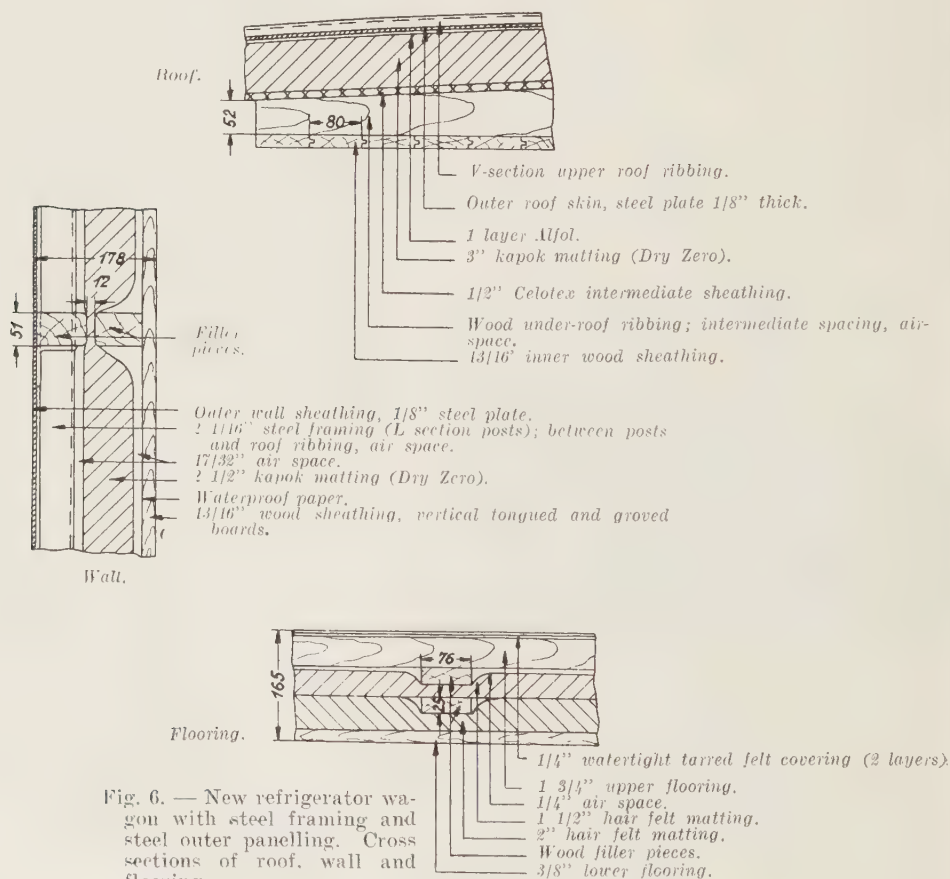


Fig. 6. — New refrigerator wagon with steel framing and steel outer panelling. Cross sections of roof, wall and flooring.

outer and inner filler pieces (see fig. 6, section of side wall) do not join the outer double wall to the inner panelling

but end in the filler pieces, so that no heat conducting channels are formed between the outside and the inside.

(To be continued.)

[ 585 (095 (497.2) ]

## Fifty years of the Bulgarian State Railways <sup>(1)</sup> (1888-1938).

### V. — Traffic.

The narrow-gauge lines of the Bulgarian system were only used entirely for public services after the 1914-1918 war. The volume of traffic on these lines only represents 3 % of the total traffic of the Bulgarian State Rys., so that we will only deal with the traffic on the standard-gauge lines.

#### 1. Passenger traffic.

The growth of the passenger traffic is shown by the figures given below :

| Year. | Passengers carried.<br>Millions. | Passenger-km.<br>(Passenger-miles).<br>Millions. | Average distance travelled per passenger.<br>Km. (Miles). |
|-------|----------------------------------|--|---|
| 1889  | 0.11                             | 10 (6.2)   | 84 (52.2)   |
| 1909  | 2.8                              | 197 (122.4)                                      | 70 (43.5)   |
| 1929  | 9.4                              | 647 (402)  | 69 (42.9)   |
| 1937  | 10.2                             | 685 (425.6)                                      | 67 (41.6)   |

Thus, during the period in question the number of passengers carried increased in the ratio of 1 to 93, a very large increase due to the growing density of the railway traffic and the increase in the mileage operated. The same reasons explain the increase in the ratio of 1 to 69 of the number of passenger-miles. The difference between the increase in the number of passengers and the number of passenger-miles is due to the smaller average mileage per passenger, which is mainly due to the

increase in the density of the population of Bulgaria.

This great increase in the volume of passenger traffic was accompanied by changes in the composition of the traffic, as shown below :

| Year.    | Total passenger-miles. |                 |                 |
|----------|------------------------|-----------------|-----------------|
|          | 1st class.<br>%        | 2nd class.<br>% | 3rd class.<br>% |
| 1909 . . | 1.77                   | 14.04           | 84.19           |
| 1929 . . | 0.41                   | 6.30            | 93.29           |
| 1937 . . | 0.23                   | 4.27            | 95.50           |

This table shows that as regards the user of the different classes, the tendencies noted during the development of the Bulgarian railways have been the same as on other railways, in particular : an appreciable falling off in the number of 2nd-class passengers, and even more in the number of 1st-class passengers.

#### 2. Volume of goods traffic.

The development of the goods traffic is shown by the following figures :

| Year. | Tonnes carried.<br>Millions. | Tonne-km.<br>(Ton-miles).<br>Millions. | Average transport distance of a tonne in km. (a ton in miles). |
|-------|------------------------------|--|--|
| 1889  | 0.14                         | 12 (7.33)                              | 85 (52)  |
| 1909  | 1.4                          | 188 (115.0)                            | 132 (80.7)   |
| 1929  | 3.7                          | 675 (412.8)                            | 183 (111.9)  |
| 1937  | 3.9                          | 728 (445.2)                            | 186 (113.7)  |

(1) Concluded from April 1940 number, p. 144.

These figures show that, during the 50 years under consideration, the tonnage of goods carried has increased in the ratio of 1 to 29, a considerable increase due to the greater mileage of lines in operation as well as the increase in the density of the traffic. The same reasons explain that the number of ton-miles increased 60 times during the same period. The difference between the increase in the number of ton-miles and the quantity of goods carried is due to the doubling of the average mileage per tonne carried, which is a result of the reduction in the rates, as well as the increased mileage of lines in operation.

The great increase in the volume of goods traffic was accompanied by changes in the composition of this traffic, which is brought out by the following table :

| Year.    | Cereals.             |       | Coal.                |       |
|----------|----------------------|-------|----------------------|-------|
|          | Thousands of tonnes. | % (*) | Thousands of tonnes. | % (*) |
| 1894 . . | 135                  | 34.5  | 45                   | 11.5  |
| 1909 . . | 313                  | 22.0  | 141                  | 9.9   |
| 1929 . . | 371                  | 20.9  | 767                  | 10.1  |
| 1937 . . | 535                  | 13.7  | 889                  | 22.8  |

As regards the transport of cereals, it should be remembered that the difference between the years 1929 and 1937 is due to the better harvest in 1937. The great changes in the composition of the traffic during the years in question are the result of the evolution of the economic situation in Bulgaria, characterised by the great increase (absolute and relative) in the coal traffic.

### 3. Density of traffic.

The development of the traffic density is shown in the following table :

---

(\*) Percentage of the total quantity of goods carried.

| Year.            | Thousands of passenger-km.<br>(of passenger-miles). | Thousands of tonne-km.<br>(of ton-miles). |
|------------------|---|---|
|                  | Ratio 1937/1889. $\times 10$                        | $\times 8$                                |
| 1889 . . . .     | 24 (14.9)   | 32 (19.6)                                 |
| 1909 . . . .     | 121 (75.2)  | 115 (70.3)                                |
| 1929 . . . .     | 269 (67.2)  | 281 (171.9)                               |
| 1937 . . . .     | 242 (150.4)   | 257 (157.2)                               |
| Ratio 1937/1889. | $\times 10$   | $\times 8$                                |

If the traffic density be taken as expressing the degree of utilization of the railway, the information given above shows that a great increase in the degree of utilization of the railway has been achieved in the case of transport in Bulgaria. This increase is the result above all of the general progress made in Bulgaria in the economic and cultural field, and secondly is due to the increase in the density of the population from 34 inhabitants per km<sup>2</sup> (88 per sq. mile) in 1889 to 61 per km<sup>2</sup> (158 per sq. mile) in 1937.

This progress is due to a great many different factors combined, amongst which the railway plays the most important part, as it has greatly improved transport conditions in Bulgaria, thanks to the great reduction in the transport rates and appreciable improvement of the railway services.

During the last few years the development of railway traffic in Bulgaria has been hampered by road motor competition. For this reason latterly great efforts have been made in Bulgaria, also, to co-ordinate rail and road transport. This co-ordination is vital to the interests of the national economy in which the railway holds one of the foremost places. No definitive results have, however, been obtained to date.

### 4. Characteristics of the transport services.

(a) *Speed.* — The information given below shows the development in the

speed attained in the case of passenger traffic during the period under review.

The luxury train, the Simplon-Orient Express, runs over the Yugoslavian frontier-Dragoman-Sofia-Svilengrade-Turkish frontier international line. This line is 360 km. (223.7 miles) long. The speeds reached in succession on this international service over the Bulgarian section have been as follows :

| <i>From the timetable for the year :</i> | <i>Maximum speed.<br/>Km./h. (m.p.h.)</i> | <i>Average speed.<br/>Km./h. (m.p.h.)</i> |
|--|---|---|
| 1889 . .                                 | 45 (28)                                   | 29 (18)                                   |
| 1909 . .                                 | 60 (37.3)                                 | 35 (21.7)                                 |
| 1929 . .                                 | 65 (40.4)                                 | 36 (22.4)                                 |
| 1937 . .                                 | 70 (43.5)                                 | 41 (25.5)                                 |

The Dragoman-Sofia-Bélovo section (150 km. = 93 miles long) of the international line in question is very hilly, which in view of the considerable increase in the weight of the Simplon-Orient Express has prevented much progress being made in recent years as far as the speed of this luxury train is concerned.

In 1899 the main line in the north of the country, from Sofia to Varna (541 km. = 336.2 miles) was opened to traffic; the increase in the speed of the express trains running over this line have been as follows :

| <i>From the timetable for the year :</i> | <i>Maximum speed.<br/>Km./h. (m.p.h.)</i> | <i>Average commercial speed.<br/>Km./h. (m.p.h.)</i> |
|--|---|--|
| 1889 . .                                 | 40 (25)                                   | 20 (12.5)  |
| 1909 . .                                 | 60 (37.3)                                 | 39 (24.2)  |
| 1929 . .                                 | 60 (37.3)                                 | 40 (25.0)  |
| 1937 . .                                 | 70 (43.5)                                 | 47 (29.2)  |

These figures show the evolution of the speeds of the fastest trains on the Bulgarian system. As for the speed of the trains in general, in the case of the passenger services, the following figures have been taken from the annual statistics of the Bulgarian railways :

| <i>From the timetable for the year :</i> | <i>Average commercial speed.<br/>Km./h. (m. p. h.)</i> |                         |
|--|--|-------------------------|
|  | <i>Express trains.</i>                                 | <i>Stopping trains.</i> |
| 1929 . . .                               | 36 (22.4)  | 29 (18)                 |
| 1933 . . .                               | 38 (23.6)  | 31 (19.3)               |
| 1937 . . .                               | 40 (25)  | 32 (19.9)               |

During the first few years the average overall speed of the goods trains on the Bulgarian railways was only 15 km. (9.3 miles) an hour at the most, whereas in 1937 it was 25 km. (15.5 miles) an hour, this progress being due above all to the introduction of through goods trains.

The details given above show that in this field likewise the Bulgarian Railways, during the period of fifty years under review, have made steady progress, if not very great progress. The improvement of the locomotives and rolling stock of the Bulgarian State Railways has generally led to higher running speeds; on the other hand, however, the technical conditions of the lines are in general unfavourable. The following particulars about the gradient section of the standard-gauge lines relate to the end of 1937 :

|  | <i>Of the whole system.</i> |
|--|-----------------------------|
| On the level . . . . .                                   | 27.5 %                      |
| Gradients of 1 in 200 . . . . .                          | 27.7 %                      |
| Gradients of more than 1 in 200 up to 1 in 100 . . . . . | 17.8 %                      |
| Gradients of more than 1 in 100 up to 1 in 40 . . . . .  | 27.0 %                      |

These mountainous lines often have very sharp curves, as the following figures show :

|   | <i>Of the whole system.</i> |
|---|-----------------------------|
| Straight sections . . . . .                             | 65.4 %                      |
| Curves of 500 m. (25 chains) radius or more . . . . .   | 15.1 %                      |
| Curves of less than 500 m. (25 chains) radius . . . . . | 19.5 %                      |

The causes of the poor technical conditions of the Bulgarian lines are mainly

the small amount of traffic originally expected, the bad state of the roads in Bulgaria, and the difficulty of raising money for capital expenditure.

During the last few years, the amount of traffic has increased considerably on certain sections of the main lines; on the other hand the conditions for road traffic have also improved, owing to the great increase in motor traffic in Bulgaria. In view of this situation, it has been found necessary to double certain short sections of main line; it has also been decided to increase the rolling stock by railcars in order to speed up the passenger services, and to equip goods wagons with the continuous brake in order to be able to speed up the goods trains as well. These improvements to the rolling stock, however, have to be subordinated to the financial resources available, on which the absolutely indispensable improvements to the layout and profile of certain sections of the main lines of the Bulgarian State Rys. are also dependent.

(b) *Safety*. — Towards the end of 1923, obligatory insurance of passengers against accident was introduced on the Bulgarian State Rys.; the premium for this insurance is included in the fares. This has made it possible to keep statistics of all the accidents to passengers on the railway since 1924. These statistics show that on the standard-gauge lines 92 passengers were killed and 238 injured between 1924 and 1937. As the number of passenger-km. for the period in question was 14 253 millions, 6 passengers are killed and 17 injured per 1 000 000 passenger-km. (i. e. 10 killed and 27 injured per 1 000 000 passenger-miles) These figures show that the safety on the Bulgarian State Railways is nearly as good as on other European railways.

During the period under review the development of the safety of goods traffic has also conduced to the bringing

down to a minimum the damage to goods due to accident, defective rolling stock, or delays in delivery. Owing to these improvements in the security of the goods traffic during the last few years, the premiums for insuring goods carried by rail have been reduced to about the same level as in other countries.

(c) *Regularity*. — Since 1920 detailed statistics are also available about train delays in Bulgaria. These statistics bring out the fact that from 1920 to 1937 the regularity of the train services has increased progressively. During the last few years 9/10ths of the trains have left the departure stations at the time laid down in the timetables; delays on the journey were altogether insignificant as shown hereafter, so that it can be stated that 8/10ths of all the trains reached the destination stations at the times given in the timetables.

| Category of train. | Average delay en route,<br>in minutes, per 100 train-km.<br>(per 100 train-miles). |              |             |
|--------------------|--|--------------|-------------|
|                    | 1920   | 1929         | 1937        |
| Express .          | (*)  | 3' (4'26")   | 1' (1'36")  |
| Local . .          | 7' (11'16")  | 2' (3'13")   | 2' (3'13")  |
| Composite          | 27' (43'27")   | 14' (22'32") | 6' (9'39")  |
| Goods .            | 70' (112'39")  | 23' (37')    | 10' (16'5") |

(d) *Facilities*. — The facilities offered depend to a large extent on the relative number of stations, which is shown in the following table :

| Year. | Lines in operation.<br>Km. (Miles) | Number of stations. | Average distance between stations. |
|-------|------------------------------------|---------------------|------------------------------------|
|       |                                    |                     | Km. (Miles).                       |
| 1889  | 383 (238)                          | 19                  | 20.2 (12.55)                       |
| 1909  | 1 692 (1 051)                      | 104                 | 16.0 (9.9)                         |
| 1929  | 2 444 (1 519)                      | 223                 | 10.9 (6.77)                        |
| 1937  | 2 910 (1 808)                      | 276                 | 10.5 (6.52)                        |

The figures given in the last column show that during the period in question the number of stations has been doubled, which considerably facilitates the traf-

(\*) No express train services.

fic, especially in the case of the goods. This relative increase in the number of stations was made necessary by the increased number of trains, as the following figures show :

| Year.          | Average number<br>of trains a day. |
|----------------|------------------------------------|
| 1889 . . . . . | 3                                  |
| 1939 . . . . . | 7                                  |
| 1929 . . . . . | 11                                 |
| 1937 . . . . . | 11                                 |

These figures show that during this period the traffic density has been nearly quadrupled, which made it necessary to increase the facilities offered, especially in the case of the passenger traffic.

As regards the goods traffic, one of the chief facilities which has had an effect on the development of road traffic is the introduction of special arrangements to load goods directly onto railway wagons from the consignor's premises and unload them on the consignee's premises. On the Bulgarian State Rys. this important facility has been extended quite satisfactorily, seeing that the railways have rented part of

their lands for the building of warehouses, have built sidings to mines and quarries, and above all have encouraged the construction of private sidings, as the following figures prove :

| Year.        | Number of<br>private sidings. | Total length.<br>Km.(Miles). |
|--------------|-------------------------------|------------------------------|
| 1895 . . . . | 1                             | 0.5 (0.3)                    |
| 1909 . . . . | 5                             | 2.1 (1.3)                    |
| 1929 . . . . | 61                            | 38.6 (24)                    |
| 1937 . . . . | 74                            | 50.3 (31.3)                  |

Owing to the considerable extension of the door to door services during the last few years, 80 % of the goods traffic on the Bulgarian State Rys. is conveyed by this method, which is very similar to motor transport.

VI. — Capital expenditure.

1. Sources : State loans.

(a) Loans from abroad.

The greater part of the capital needed to purchase the private lines, build new lines, and equip them with rolling stock, during the period of 50 years under review, has been raised by loans from abroad, i. e. :

| State<br>loans.<br>Year. | Issued in the following countries :        | Product<br>of loan,<br>in millions<br>of gold-leva | Portion allocated<br>to capital expenditure. |       |
|--------------------------|--|--|--|-------|
|                          |  |  | Millions<br>of gold-leva                     | %     |
| 1888                     | England . . . . .                          | 46.8   | 46.8   | 100.0 |
| 1889                     | Austria, England, Germany . . . .          | 25.5   | 13.0   | 50.9  |
| 1892                     | Austria, England, Germany, etc. . .        | 110.1  | 86.6   | 78.7  |
| 1904                     | England, France, Germany, etc. . . .       | 80.4   | 20.9   | 25.9  |
| 1907                     | England, France, Germany, etc. . . .       | 120.1  | 35.3   | 29.4  |
| 1909                     | Russia . . . . .                           | 82.0   | 42.1   | 51.4  |
| 1909                     | England, France, Germany, etc. . . .       | 86.0   | 27.7   | 32.3  |
| 1923                     | France, Belgium, etc. . . . .              | 12.1   | 1.1  | 9.1   |
| 1926                     | England, U. S. A., Holland, etc. . . .     | 73.2   | 10.0   | 13.7  |
| 1928                     | England, U. S. A., France, Holland, etc. . | 126.0  | 10.4   | 8.2   |

The above details show that up to the time of the Balkan War (1912-1913), Bulgaria had obtained 550.9 million gold-leva by loans from abroad, the part allocated to capital expenditure on the railways being 267.6 million gold-leva, or 48.7 % of the total product of the loans. The product of loans after the 1914-1918 war amounts to 211.3 million gold-leva, 21.5 millions being for capital expenditure, or 10.2 %. Altogether during the 50 years in question, the capital obtained from loans abroad has reached 762.2 million gold-leva, 289.1 million being for capital expenditure on the railways, or 37.9 % of the total.

The main conditions of these loans are given below :

| State<br>loans. | Year. | Issue price. | Annual interest. |         | Terms for<br>repayment.<br>Years. | Special guarantees :                      |
|-----------------|-------|--------------|------------------|---------|-----------------------------------|---|
|                 |       |              | Nominal.         | Actual. |                                   |   |
|                 | 1888  | par value    | 6.00             | 6.00    | 33                                | Without special guarantee.                |
|                 | 1889  | 85 and 87    | 6.00             | 7.50    | 33                                | First mortgage on railway lines.          |
|                 | 1892  | 83-89        | 6.00             | 7.34    | 33                                | First mortgage on railways and harbours.  |
|                 | 1904  | 82           | 5.00             | 7.03    | 50                                | Receipts from stamps and duty on tobacco. |
|                 | 1907  | 85           | 4.50             | 5.94    | 60                                | Do.                                       |
|                 | 1909  | par value    | 4.75             | 4.75    | 75                                | No special guarantees.                    |
|                 | 1909  | 96           | 4.50             | 5.51    | 50                                | Do.                                       |
|                 | 1923  | par value    | 6.50             | 6.50    | 30                                | Do.                                       |
|                 | 1926  | 87 and 88    | 7.00             | 8.37    | 40                                | Receipts from excise duties.              |
|                 | 1928  | 91           | 7.50             | 8.43    | 40                                | Receipts from customs duties.             |

Careful examination of the conditions under which the Bulgarian loans were made shows that the conditions before the world war were generally more favourable than those obtained afterwards.

#### (b) Domestic loans.

Up to the 1914-1918 war no domestic loans were made in Bulgaria to obtain capital, owing to the shortness of capital in the country, some idea of which can be obtained when it is remembered that in 1897 the post office savings bank only

held 2 million gold-leva, and 43 millions in 1911.

After the 1914-1918 war it was difficult to borrow money abroad, whereas local capital had greatly increased, so that between 1921 and 1937 money was borrowed in the country to a total amount of 16.5 million gold-leva, with an actual interest of 4.5 to 6.5 % per annum, the redemption period being 10 to 40 years, without special guarantee.

#### (c) Loans from special railway funds.

In 1929, special « Renewal » and « Fire Insurance » Funds were introduced for the State Railways. Between 1929 and 1937, 17 million gold-leva of the

available capital of these funds were transferred to the railway capital account in the form of loans.

#### 2. Other sources.

So as not to hinder the development of the system too much, and in view of the great difficulty of obtaining the necessary capital by State loans alone, the capital invested in the Bulgarian Rys. was increased from other sources, which may be classified as follows : Railway taxes, State taxes, corvees, and sundry sources.

*(a) Railway taxes.*

From 1889 to 1928, 79 million gold-leva were collected from the balance of the operating receipts of the railway for capital expenditure on rolling stock and improvement of the lines in operation. In 1929 a radical reorganisation of the finances of the Bulgarian State Rys. was taken in hand, and it was decided that part of the annual profits could be used to increase the capital invested. Between 1929 and 1937, three million gold-leva were collected from the working profits for 1929 to improve the lines being worked.

Special surtaxes were introduced in 1926, the receipts from which are not counted as operating receipts but as a source of capital to improve the lines in operation. From 1926 and 1937, 13 million gold-leva were collected in this way to increase the available capital.

Consequently railway taxes have provided 95 million gold-leva of railway capital during the period in question.

*(b) State taxes.*

Special taxes were introduced in 1925, the receipts from which were to contribute to speeding up the construction of new lines. Between 1925 and 1937, this new source has added 23 million gold-leva to the capital invested.

Up to the financial reorganisation of 1929 mentioned above, from 1888 to 1928, 59 million gold-leva were collected from the receipts of other taxes for the construction of new lines.

In this way during the period in question 82 million gold-leva were obtained by State taxes for the capital invested in the State Railways.

*(c) Corvees.*

The law of 1885 introducing State ownership of the railways provided that when the State was building a line, every inhabitant of the department through

which it ran owed 10 days labour for the necessary earthworks. Labour was only obtained in this way between 1889 and 1893, the value being estimated at 0.4 million gold-leva.

The said law of 1885 also stipulated that when the State was building new railway lines, the army was to assist with the work. This was only enforced between 1889 and 1890, the earthworks completed during that period being valued at 0.6 million gold-leva.

When railway lines were being built during the wars of 1912-1913 and 1915-1918, the army completed work valued at 3.8 million gold-leva. It follows that during the period in question military labour completed work valued at 4.4 million gold-leva.

The law of 1925 introduced a special tax, in labour or in money. This tax between 1925 and 1937 contributed towards the construction of new lines by labour supplied a total value of 16.6 million gold-leva, which figure may be considered as a very favourable one.

To sum up, during the period under review, it follows that 21.4 million gold-leva were contributed in the form of labour towards the capital invested.

*(d) Sundry sources.*

3 million gold-leva have been obtained from other sources of capital. The greater part represents the value of the land required by the railway, which according to the law on the construction of railways was ceded by the communes and departments free of charge. In addition, in some cases the communes contributed in labour or money towards the cost of the station buildings.

### **3. Recapitulation of the sources from which the invested capital was obtained.**

The information given above about the sources of capital invested in the railway are summed up in the following table :

| <i>Sources of capital invested.</i> | <i>Investments<br/>(in millions of gold-leva)<br/>during the years</i> |         |         | <i>Percentage of total<br/>invested during the years</i> |         |           |
|-------------------------------------|--|---------|---------|--|---------|-----------|
|                                     | 1888-1911  | 1912-37 | 1888-37 | 1888-1911  | 1912-37 | 1888-1937 |
| <b>STATE LOANS.</b>                 |  |         |         |  |         |           |
| Loans abroad . . . . .              | 268  | 21      | 289     | 85.8   | 10.0    | 55.3      |
| Domestic loans . . . . .            | —  | 17      | 17      | —  | 8.1     | 3.2       |
| Loans on railway funds . . . . .    | —  | 17      | 17      | —  | 8.1     | 3.2       |
| Total amount borrowed               | 268  | 55      | 323     | 85.8   | 26.2    | 61.7      |
| <b>OTHER SOURCES.</b>               |  |         |         |  |         |           |
| Railway taxes. . . . .              | 16   | 79      | 95      | 5.1  | 37.4    | 18.1      |
| Taxes . . . . .                     | 26   | 56      | 82      | 8.5  | 26.2    | 15.6      |
| Corvees . . . . .                   | 1  | 20      | 21      | 0.3  | 9.3     | 4.0       |
| Various . . . . .                   | 1  | 2       | 3       | 0.3  | 0.9     | 0.6       |
| Total from other sources            | 44   | 157     | 201     | 14.2   | 73.8    | 38.3      |
| Sum total                           | 312  | 212     | 524     | 100.0  | 100.0   | 100.0     |

The financial development during the 50 years in question can be divided into two more or less equal periods, as shown in the above table. This table brings out the fact that money borrowed by the State from abroad was practically the only source of capital between 1888 and 1911, during which period other sources were of very insignificant importance; the latter, however, were the main source of capital between 1912 and 1937, during which years special taxes and dues, and even special corvees were introduced. This shows that the tendency has been towards continuous development of the railway system, in spite of the great difficulties arising after the 1914-1918 war, especially, as regards obtaining sufficient capital.

#### 4. Capital spent on building the lines.

The following table shows how the capital spent on the Bulgarian Railways has increased :

| <i>At 31st December<br/>of the year :</i> | <i>Length of<br/>the system.<br/>Km. (Miles).</i> | <i>Capital expenditure in gold-leva.</i> |   |                                 |
|---|---|--|---|---------------------------------|
|   |   | <i>Total.<br/>Millions.</i>              | <i>Per km. (per mile)<br/>of line.<br/>Thousands.</i> | <i>Per unit<br/>of traffic.</i> |
| 1889 . . . . .                            | 337(*) (209) (*)                                  | 52                                       | 154 (247.8)   | 2.63                            |
| 1909 . . . . .                            | 1 692 (1 051)                                     | 226                                      | 133 (214.0)   | 0.60                            |
| 1929 . . . . .                            | 2 916 (1 812)                                     | 332                                      | 114 (183.5)   | 0.24                            |
| 1937 . . . . .                            | 3 366 (2 091)                                     | 409                                      | 121 (194.7)   | 0.28                            |
| Ratio 1937/1889 . . . . .                 | × 10  | × 8                                      | — 21 %  | — 90 %                          |

(\*) Excluding the 46 km. (28.6 miles) long Vakarel-Bélevo line.

The details given above show that the increase in the total amount of the capital invested in the lines is due solely to the increased length of the system.

At the beginning of the period in question, the average value of the capital invested per mile of line was higher, simply on account of the high price for purchasing the Roussé-Varna line. This relative value of the capital invested declined during the period from 1909 to 1937, chiefly owing to the extension of the narrow-gauge lines and the construction of approximately 400 km. (250 miles) of secondary lines with old rails recovered when relaying the main lines.

Natural conditions in Bulgaria are usually bad for railway construction; but the capital invested per mile of line is relatively low, for the following reasons: relatively low cost of labour, the low standard of the lines (due above all to the small amount of traffic), and relative cheapness of land in Bulgaria.

### 5. Capital invested in the rolling stock.

The evolution of this capital is shown by the following table :

| <i>Capital invested in gold-leva.</i>     |   |                             |  |                                 |
|---|---|-----------------------------|--|---------------------------------|
| <i>At 31st December<br/>of the year :</i> | <i>Length of<br/>the system.<br/>Km. (Miles).</i> | <i>Total.<br/>Millions.</i> | <i>Per Km. (per mile).<br/>of line.<br/>Thousands.</i> | <i>Per unit<br/>of traffic.</i> |
| 1889 . . . . .                            | 337 (209)   | 6                           | 18 (29)  | 0.32                            |
| 1909 . . . . .                            | 1 692 (1 051)                                     | 25                          | 15 (24.1)  | 0.07                            |
| 1929 . . . . .                            | 2 916 (1 812)                                     | 92                          | 32 (51.5)  | 0.07                            |
| 1937 . . . . .                            | 3 366 (2 091)                                     | 105                         | 31 (49.9)  | 0.07                            |
| Ratio 1937/1889 .                         | × 10  | × 18                        | × 2  | — 80 %                          |

These details in conjunction with those relating to the growth of the traffic show that during the 50 years in question, the total amount of the capital invested in the rolling stock has increased, chiefly on account of the increase in the length of the system and the volume of traffic, and that the capital invested per mile has increased solely on account of the increase in the amount of traffic. Already in 1909 normal utilization of the capacity of the rolling stock had been obtained, thanks to which the capital per unit of traffic was considerably reduced; its relative value has remained constant from 1909 to 1937.

### 6. Total capital invested.

The evolution of this capital has been shown above as regards that invested in the construction of the lines and in the rolling stock, and the following table has been drawn up in accordance with these facts :

| <i>Capital invested in gold-leva.</i>     |  |                             |   |                                 |
|---|--|-----------------------------|---|---------------------------------|
| <i>At 31st December<br/>of the year :</i> | <i>Length of<br/>the system.<br/>Km. (Miles)</i> | <i>Total.<br/>Millions.</i> | <i>Per km. (per mile)<br/>of line.<br/>Thousands.</i> | <i>Per unit<br/>of traffic.</i> |
| 1889 . . . . .                            | 337 (209)  | 58                          | 172 (276.8)   | 2.95                            |
| 1909 . . . . .                            | 1 692 (1 051)                                    | 251                         | 148 (238.2)   | 0.67                            |
| 1929 . . . . .                            | 2 916 (1 812)                                    | 424                         | 146 (235)   | 0.31                            |
| 1937 . . . . .                            | 3 366 (2 091)                                    | 514                         | 152 (244.6)   | 0.35                            |
| Ratio 1937/1889 .                         | × 10   | × 9                         | — 12 %  | — 87 %                          |

In Section 3 above, we pointed out that up to the end of the year 1937, 524 million gold-leva had been invested in the railways. Of these 524 millions, 514 have been invested in the system now under operation, and the remaining 10 millions in the labour in hand for the construction of new lines, which, however, had not yet been completed by the end of 1937.

## VII. — Operating results.

### 1. Expenditure.

In order to give a clear idea of the financial position of the Bulgarian State Rys. between 1888 and 1938, we will consider first of all the increase in expenditure, which in general precedes and determines the railway receipts.

#### (a) Operating costs.

The development of this expenditure

for the whole of the system has been as follows :

| Year.          | Operating costs.                          |  |   |
|----------------|---|--|---|
|                | Total,<br>in<br>thousands<br>of gold-leva | Per km.<br>(per mile)<br>of line,<br>in thousands<br>of gold-leva. | Per unit<br>of traffic,<br>in centimes<br>of gold-leva. |
|                |   |  |   |
| 1889 . . . . . | 2 221                                     | 5.8 (9.3)  | 10.36   |
| 1909 . . . . . | 13 874                                    | 8.5 (13.7)   | 3.58  |
| 1929 . . . . . | 42 673                                    | 14.9 (24)  | 3.06  |
| 1937 . . . . . | 41 514                                    | 12.7 (20.4)  | 2.95  |
| Ratio          |   |  |   |
| 1937/1889      | × 19                                      | × 2  | — 71 %  |

During the period under review, the increase recorded in the total amount of working expenses is due chiefly to the increase in the mileage in operation, and in the second place to the increase in the volume of traffic; the operating costs per mile of line increased solely as a result of the increase in the amount of traffic, but to a smaller extent, seeing that the operating costs per unit of traffic have considerably decreased. These expenses express the actual operating cost per unit of traffic, and we would like to point out that the favourable evolution of these costs is due to the following principal reasons : Considerable increase in the volume of traffic; technical progress of the railway, and considerable decrease in the cost of the coal consumed by the State Rys. The following figures relate to the price of coal during the 1889 to 1937 period :

| Year.          | Price per tonne in gold-leva. |                 |
|----------------|-------------------------------|-----------------|
|                | Foreign coal.                 | Bulgarian coal. |
| 1889 . . . . . | 40                            | (*)             |
| 1909 . . . . . | 26                            | 13              |
| 1929 . . . . . | (**)                          | 15              |
| 1937 . . . . . | (**)                          | 12              |

From 1888 to 1892 the Bulgarian State Rys. only used imported coal, the cost of which was relatively high. In 1893

the line from Sofia to Pernik (chief Bulgarian State coal mines) was opened to traffic, so that the railway was able to obtain native coal at a much lower cost; all the same, one ton of imported coal equals 1 1/2 ton of coal from the Pernik mines. Since the 1914-1918 war the Bulgarian Railways only use Bulgarian coal, from either State owned or private mines.

#### (b) Financial charges.

The operating costs of the Bulgarian State Rys. also include the cost of renewal, so that the financial charges consist almost entirely of the interest on monies borrowed by the State Rys., i. e. State debts contracted in order to purchase private lines, build new lines, and buy rolling stock.

The following table shows the evolution of the financial charges for the whole system :

| Year.          | Financial charges.                   |   |  |
|----------------|--------------------------------------|---|--|
|                | Total.<br>Thousands<br>of gold-leva. | Per km.<br>(per mile)<br>of line,<br>Thousands<br>of gold-leva. | Per unit of<br>traffic in<br>centimes of<br>a gold-leva. |
|                |                                      |   |  |
| 1909 . . . . . | 2 520                                | 6.6 (10.6)  | 11.71  |
| 1929 . . . . . | 10 547                               | 6.5 (10.45)   | 2.74   |
| 1937 . . . . . | 5 797                                | 2.0 (3.2)   | 0.42   |
| 1889 . . . . . | 7 156                                | 2.2 (3.5)   | 0.51   |

During the period in question, the total amount of the financial charges has been trebled, solely on account of the increase in the length of the system. During the same period, however, this length has increased in the ratio of 1 to 8 1/2, i. e. in a much greater proportion than the total amount of the financial charges. As a result, the financial charges per mile of line have greatly decreased between 1889 and 1937, for the following reasons : Increase of the capital invested between 1912 and 1937 from sources which did not involve further debts for the State Rys.; redemption of a large amount of the State loans

(\*) No Bulgarian coal was used.

(\*\*) Foreign coal was no longer used.

contracted to obtain original capital; and lower rate of actual interest on the State loans due to the poor financial position of the State after the 1914-1918 war and the economic crisis which began in 1929.

The decrease in the financial charges per mile of line went hand in hand with a great increase in the traffic density, which led to a 96 % decrease in the financial charges per unit of traffic. The details and explanations given above show that between 1889 and 1937 the operating costs have greatly decreased for the following reasons: Increase of the volume of traffic, additional capital obtained from sources which did not involve increased indebtedness; redemption of a large part of the State loans, and a lower rate of actual interest on the remaining loans.

(c) *Total general expenditure.*

Examination of the operating costs and financial charges shows that the total general costs can be established as follows:

| Year.             | Cost per unit of traffic,<br>in centimes of a gold-leva. |                    |        |
|-------------------|--|--------------------|--------|
|                   | Operating costs.   | Financial charges. | Total. |
| 1889 . .          | 10.36  | 11.71              | 22.07  |
| 1909 . .          | 3.58   | 2.74               | 6.32   |
| 1937 . .          | 3.06   | 0.42               | 3.48   |
| 1929 . .          | 2.95   | 0.51               | 3.46   |
| Ratio             |  |                    |        |
| 1937/1889. — 71 % | — 96 %   | — 85 %             |        |

The sum total of the costs enables the cost per unit of traffic to be estimated. The above table shows that between 1889 and 1937 the costs have been appreciably reduced, chiefly on account of the decrease in the financial charges, and also of the operating costs per unit of traffic. These details about the reduction of various factors of the total general expenditure show that on the Bulgarian State Rys. the cost per unit of traffic greatly decreased between 1889 and 1937 for the following reasons: In-

creased traffic density, increase in the capital invested obtained from sources other than loans, redemption of a considerable part of the State loans, technical progress of the railways, fall in the price of coal, and lower actual rate of interest on State loans.

## 2. Receipts.

### (a) *Rating policy.*

The part played by the railway being one of the main factors in the general development of a country, the Bulgarian Railways adopted the following principle for their rates policy: Reduction of the cost of transport must lead above all to a reduction in the rates, as this is the essential factor in maintaining the traffic, an indispensable condition if the railway is to play its part properly; reduction in the cost of transport should contribute very little to reducing the losses or earning a profit; the latter should be the result solely of a great increase in the traffic volume.

In Bulgaria the rightness of such a railway rating policy has never been disputed. It was, however, only followed for a relatively short time, and about 1900 a new rating policy came into force based on the principle that the reduction in the cost of traffic should contribute above all to a reduction in the losses or increase in the profits, although this in no way corresponds to the increase in the traffic density; the reduction in the cost of transport should involve a relatively unimportant reduction in the rates, in spite of the fact that these are the essential element in retaining the traffic.

The tendency of this new rating policy was also reflected in the law of 1929 on the organisation and administration of the railways, in which certain fundamental rules were laid down about their commercial operation. One of these at least can be usefully quoted: Clause 2 states expressly that the Bulgarian State Rys. shall be so operated as to pay.

The bad state of the State finances during the last ten years has encouraged the tendency to get as much profit from the State Rys. as possible, both openly and covertly. The economic situation in Bulgaria made this possible only by stopping more or less completely the normal evolution of the transport rates, and even involved regressive measures, as when the rates were increased in 1937.

(b) *Transport rates.*

The evolution in the rates on the Bulgarian State Rys. are shown in the following table :

| <i>Average receipts in gold-centimes.</i> |                                    |                                  |                         |  |
|---|------------------------------------|----------------------------------|-------------------------|--|
| Year.                                     | Per pass.-km.<br>(per pass.-mile). | Per tonne-km.<br>(per ton-mile). | Per unit<br>of traffic. | Average cost<br>per unit of traffic<br>in gold-centimes. |
| 1889 . . . . .                            | 7.00 (11.26)                       | 11.00 (17.98)                    | 9.17                    | 22.07  |
| 1900 . . . . .                            | 3.75 (6.03)                        | 6.32 (10.33)                     | 5.41                    | 9.32   |
| 1909 . . . . .                            | 4.07 (6.55)                        | 5.80 (9.48)                      | 5.14                    | 6.32   |
| 1911 . . . . .                            | 4.69 (7.55)                        | 5.67 (9.27)                      | 5.47                    | 6.07   |
| 1929 . . . . .                            | 2.74 (4.41)                        | 4.65 (7.60)                      | 3.80                    | 3.48   |
| 1936 . . . . .                            | 2.49 (4.01)                        | 4.26 (6.97)                      | 3.54                    | 3.71   |
| 1937 . . . . .                            | 2.65 (4.26)                        | 4.52 (7.39)                      | 3.73                    | 3.46   |
| Ratio 1937/1889 . . . . .                 | — 62 %                             | — 59 %                           | — 60 %                  | — 85 %   |

This table brings out the fact that during these 50 years the reduction in both passenger fares and goods rates has been considerable, and on more or less the same level; this reduction, however, has been much less than the corresponding reduction in the cost, as the figures in the two last columns clearly show.

This unfavourable evolution of the ratio of the cost to the rates is one consequence of the rating policy mentioned above, which in turn is closely connected with the bad financial state of Bulgaria.

To appreciate the extent to which the railway rates have encouraged the general development of the country, it is necessary to compare the total amount of these rates with the average national revenue per inhabitant. In Bulgaria this

revenue in recent years has been 300 gold-francs in round figures.

During recent years the transport rates (expressed in gold-francs) of the Rumanian and Jugoslavian Rys. have been much lower than those of the Bulgarian Rys., whereas the national revenue per inhabitant of the two former States was rather higher than in Bulgaria. As a result the Bulgarian railway rates are definitely less favourable compared with those in Rumania and Jugoslavia.

They are still more unfavourable when compared with the railway rates in more highly developed countries, where such rates (in gold currency) are a little

higher, equal to, or a little lower, while the average revenue per inhabitant is 3 to 5 times higher than in Bulgaria.

(c) *Operating receipts.*

The following table shows the successive evolution of the operating receipts over the whole system :

| <i>Operating receipts.</i> |   |  |                                      |
|----------------------------|---|--|--------------------------------------|
| Year.                      | Per unit<br>of traffic.<br>Gold-<br>centimes. | Per km.<br>(per mile)<br>of line.<br>Thousands<br>of gold-leva | Total.<br>Thousands<br>of gold-leva. |
| 1889 . . . . .             | 9.17  | 5.3 (8.5)  | 2 017                                |
| 1909 . . . . .             | 5.14  | 12.2 (19.6)  | 19 830                               |
| 1929 . . . . .             | 3.80  | 18.3 (29.5)  | 52 285                               |
| 1937 . . . . .             | 3.73  | 15.9 (25.5)  | 52 170                               |
| Ratio                      |   |  |                                      |
| 1937/1889 . . . . .        | — 60 %  | × 3  | × 26                                 |

During the period considered, the average receipts per unit of traffic decreased owing to the reduction in the rates, thanks to the reduction in the cost of transport; the average receipts per mile of line have increased solely on account of the increase in the traffic density. As for the total receipts, these have increased above all on account of the increased mileage of the system, and also on account of increased traffic.

### 3. Financial results.

#### (a) Credit or debit balance.

The following table shows the evolution of the financial results :

| Year.    | Credit or debit (—) balance. |                                   |                           |
|----------|------------------------------|-----------------------------------|---------------------------|
|          | Per unit<br>of traffic.      | Per km.<br>(per mile)<br>of line. | Total.                    |
|          | Gold-<br>centimes.           | Thousands<br>of gold-leva         | Thousands<br>of gold-leva |
| 1889 . . | — 1.19                       | — 0.5 (0.8)                       | — 205                     |
| 1909 . . | 1.56                         | 3.7 (5.9)                         | 5 956                     |
| 1929 . . | 0.74                         | 3.4 (5.5)                         | 9 612                     |
| 1937 . . | 0.78                         | 3.2 (5.1)                         | 10 656                    |

Three working years only (1889, 1890 and 1892) showed a total deficit of 404 000 gold-leva, while in the other seven years the operating results showed a profit.

Consequently the financial results considered over the period follow the changes in the operating receipts and expenditures considered under sections 1 and 2 above. From the explanations given it is clear that the variation in the profits from operating the Bulgarian State Rys. is proportional, in particular, to the increase in the mileage of the system and to the growth of the traffic density.

#### (b) Operating constant.

In connection with the operating profits, the following additional information is of interest :

| Year.    | Operating<br>constant.<br>% | Ratio between<br>the profit and the |                          |
|----------|-----------------------------|-------------------------------------|--------------------------|
|          |                             | capital<br>invested.<br>%           | monies<br>borrowed.<br>% |
| 1889 . . | 112.9                       | (*)                                 | (*)                      |
| 1909 . . | 70.0                        | 2.33                                | 2.74                     |
| 1929 . . | 80.5                        | 2.38                                | 6.16                     |
| 1937 . . | 79.1                        | 2.24                                | 6.00                     |

These figures show that during the period in question the constants as a rule were favourable, especially those given in the last column, and this was due above all to the increased capital invested after 1909 from sources which did not involve the railway in debt.

#### (c) Profits and losses.

The development of the profits and losses per unit of traffic is shown below in centimes of a gold-leva :

| Year.    | Excess<br>receipts. | Financial<br>charges. | Profits (+)<br>or losses(—). |
|----------|---------------------|-----------------------|------------------------------|
| 1889 . . | — 1.19              | 11.71                 | — 12.90                      |
| 1909 . . | 1.56                | 2.74                  | — 1.18                       |
| 1929 . . | 0.74                | 0.42                  | + 0.32                       |
| 1937 . . | 0.78                | 0.51                  | + 0.27                       |

To the information given above may be added that during the said period the financial results only show a profit in 8 years (1922, 1923, 1924, 1927, 1928, 1929, 1934 and 1937), and there was a loss in the other 42 years.

The table given above shows that during the period in question the great improvement in the financial results was due to the considerable reduction in the financial charges per unit of traffic, as such charges affect the cost of working the traffic.

In accordance with the rating policy of the Bulgarian State Rys. explained above, the reduction in the cost due to the financial charges contributed above all to the reduction in the losses and increase in the profits, but on the other hand did little to reduce the transport

(\*) No profit.

rates. The result is that the evolution of the profits and losses of the Bulgarian State Rys. must be considered as unfavourable, particularly when the part the railway can play as one of the chief factors in the development of a country is borne in mind.

The following figures can be quoted as an average per kilometre and per mile of line, and for the system as a whole, bearing in mind the aforesaid evolution of the profits and losses per unit of traffic together with the increase in the mileage of the system and the growth of the traffic :

| Year.  | Profits (+) or losses (—). |                                   |                                     |
|--------|----------------------------|-----------------------------------|-------------------------------------|
|        | Per unit<br>of traffic.    | Per km.<br>(per mile)<br>of line. | As a<br>whole.<br>Thous-<br>ands of |
|        | Gold<br>centimes.          | Thousands<br>of gold-leva.        | gold-leva.                          |
| 1889 . | — 12.90                    | — 7.2 (— 11.6)                    | — 2 765                             |
| 1937 . | — 1.18                     | — 2.8 (— 4.5)                     | — 4 565                             |
| 1909 . | + 0.32                     | + 1.5 (+ 2.4)                     | + 4 403                             |
| 1929 . | + 0.27                     | + 1.1 (+ 1.8)                     | + 3 604                             |

From the point of view of the nature of the resources available to meet these losses, the period under consideration can be divided into two unequal portions : From 1888 to 1928, and from 1929 to 1937.

From 1888 to 1928 the absolute losses amounted to 195 million gold-leva, from which a profit of 8 million gold-leva has to be deducted; there was therefore a total loss of 187 million gold-leva, which was met by the receipts from State taxation.

After 1929, on account of the radical reorganisation of their finances, the Bulgarian State Rys. had to meet their losses entirely from the operating receipts. Between 1929 and 1937 the absolute losses amounted to 20 million gold-leva, 9 millions of which were covered by the profits from the years 1929, 1934 and 1937, so that at the beginning of 1938 losses totalling 11 million gold-leva still had to be made good. The amor-

tization of these losses will impede the progressive evolution of the railway rates if the provisions of the law of 1929 remain unaltered, especially if the part played by the railway as one of the most vital factors in the general development of a country is taken into account.

### Conclusion.

In the beginning of its existence as an independent State, Bulgaria was at a very low level from the point of view of economic and cultural development; as a result there was very little passenger and goods traffic; on the other hand, in view of the geographical configuration of the country, most of the traffic must go by land.

In view of this state of affairs, the creation of a railway system in Bulgaria was not inspired in the first place by the requirements of a traffic already in existence, but rather to achieve, by progressively developing what traffic there was, a speedy and appreciable improvement in the economic conditions of the country and thereby encourage its general development.

Thanks to the construction and operation of several of the main lines, an appreciable improvement was obtained in the transport services in Bulgaria, first of all in the districts served by these lines, which in turn led to a general improvement, though this did not extend beyond the limits of the districts in question.

This progress was the cause of the gradual increase in the amount of traffic owing to the extension of the system, the improvement of the services, and the reduction of the rates. This evolution in its turn encouraged the general development of the country, especially from the economic and cultural points of view.

Side by side with the development of the transport services and the general progress in Bulgaria, during the period from 1888 to 1938, the importance of the

railways has also increased. Some idea of this may be obtained from the following figures :

| Year.            | Average per inhabitant.         |                           |
|------------------|---------------------------------|---------------------------|
|                  | Passenger-km.<br>(pass.-miles). | Tonne-km.<br>(ton-miles). |
| 1889 (*) . . . . | 5 (3.1)                         | 7 (4.3)                   |
| 1909 . . . . .   | 46 (28.6)                       | 44 (26.9)                 |
| 1929 . . . . .   | 128 (79.5)                      | 123 (75.2)                |
| 1937 . . . . .   | 113 (70.2)                      | 119 (72.7)                |
| Ratio 1937/1889. | × 23                            | × 17                      |

The considerable increase in the amount of traffic, taken as an average per inhabitant, during the period in question, is due mainly to the increase in the mileage of lines in operation, the reduction of the rates, and the successful development of industry and agriculture in Bulgaria.

We have given the information about the railway system and the transport rates; below we quote figures relating to industry and agriculture.

The successful development of industry is brought out by the following figures :

| Year.          | Capital invested<br>in industry (*) in gold-leva. |                            |
|----------------|---|----------------------------|
|                | Total<br>(in millions).                           | Average<br>per inhabitant. |
| 1889 . . . . . | 4   | 1                          |
| 1909 . . . . . | 91  | 16                         |
| 1937 . . . . . | 300   | 44                         |

Owing to the fact that there was little industrial development in Bulgaria at the beginning of the period under review, railway transport of industrial products only represented a very small part of the total volume of traffic, whereas towards the end of this period, such transport represented 60 % of the total railway traffic in Bulgaria.

The information given below about exports gives some idea of the successful development of agriculture.

Percentage of total Bulgarian exports.

| Period.    | Fruit<br>and ve- |                | Animal        |                |
|------------|------------------|----------------|---------------|----------------|
|            | Cereals.<br>%    | getables.<br>% | Tobacco.<br>% | products.<br>% |
| 1886-1890. | 92.4             | 0.4            | 0.1           | 0.7            |
| 1891-1895. | 94.8             | 0.6            | 0.1           | 0.6            |
| 1906-1910. | 90.9             | 1.0            | 0.3           | 2.2            |
| 1927-1931. | 60.4             | 9.2            | 5.9           | 3.6            |
| 1932-1936. | 55.4             | 18.8           | 6.7           | 4.7            |

These figures show that during the period in question the export of large-scale agricultural products has diminished as that of the products of intensive farming increased. This favourable evolution of Bulgarian exports is proportional to the changes in agricultural tendencies in Bulgaria, especially under the decisive influence of the growth of the railways.

The extension of the Bulgarian railway system and the reduction in transport rates has increased the inland market for agricultural products, especially the products of intensive farming which are very perishable. This favourable development has gone hand in hand with the successful development of international communications in general, which has extended the international market for Bulgarian agricultural products, especially the very perishable products of intensive farming which can now be exported to relatively far off countries.

The development of the railway in Bulgaria has had a very great and favourable influence both on the development of other branches of trade in Bulgaria and on the cultural development of the country. For this reason the railways can be considered as one of the chief factors which have enabled Bulgaria to achieve such good results between 1888 and 1938 in her attempts to catch up with other countries of a higher economic and cultural level.

J. D.

(\*) Including the traffic on the private railways.

(\*) Excluding domestic industries.

## NEW BOOKS AND PUBLICATIONS.

[ 656. 25 ]

LAMALLE (U.), Ingénieur Civil des Mines, A. I. Lg., Assistant General Manager, Belgian National Railways Company. — **Cours d'exploitation des Chemins de fer. Tome II : Exploitation technique. Signalisation** (2<sup>e</sup> partie) (*Railway Operating Course. Vol. II. Technical Operation. Signalling, Part 2*). — A pamphlet (8 × 10 inches) of 72 pages, with 64 figures. — 1940; Louvain, Librairie Universitaire Ch. Uystpruyst, publisher.

In the issue of the *Bulletin* for November, 1938, we reviewed the first part of this course on railway signalling. It dealt principally with an examination of the signals usually employed, and the way in which they are used to protect points of danger on the line.

This second part is devoted to methods of protecting running movements.

In the first chapter the author explains the different methods used to maintain a space interval between trains and ensure that they do not overtake one another.

In the second he deals with ordinary block telegraph apparatus. The third and more detailed chapter describes the essential arrangement and working of the lock-and-block apparatus used in Belgium. Diagrams are given showing the principle of the interlocking between the block instruments and between them and the signals. The purpose and working of the mercury rail-contact treadle are very clearly brought out. A detailed description of what is called in Belgium the « monocinetic » device, or « one pull » lever lock, enables the reader to understand quite easily how it renders it impossible for the signalman to clear his signal twice with one release from the signal box in advance.

In chapter IV the circumstances which influence the choice of the length of block sections are explained.

In chapter V are explained the application and working of the block apparatus in the principal cases met with, namely, a through running station, a station with accommodation for local goods

service and shunting of trains, and a station where a train can take siding by shunting back or running straight in.

The various meanings attributed to block signals are analysed and explained in chapter VI.

Chapter VII, the longest of all, covers automatic block working. As is known, new installations of automatic signalling have made their appearance in recent years on the main lines and it is easy to understand why the author should have attached particular importance to the subject. After explaining the characteristics of the « normal clear » automatic signalling system and giving diagrams illustrating its principles, followed by the same treatment of the more complicated « normal danger » system, the author examines the various relays used and points out the means used to meet the danger resulting from the essentially permissive character of the signals. As a practical example he gives an installation of automatic three-position semaphore signals, worked by electric motors, with a diagram showing the movements made by the signals as the train passes through several successive block sections. Finally, the author deals with the special arrangements necessary on electrically worked lines and gives a similar series of diagrams, but showing this time colour-light signals. All the above relates to double track lines.

In a special section the author deals with the arrangements applicable to single-track lines, necessary to prevent trains from meeting each other head on.

E. M.